UNIT -1:

WAVE MOTION AND ITS APPLICATIONS

7.1 WAVEMOTION

Motion of an object is the change in its position with time. In different types of motions, some form of energy is transported from one place to another. There are two waysof transportation of energy from its place of origin to the placewhere it isto be utilized. One is the actual transport of matter. For example when a bullet is fired from a gun it carries kinetic energy which can be utilized at another place. The second method by which energy can be transported is the wave process. A wave is the disturbance in which energy is transferred from one point to other due to repeated periodic motion of particles of the medium. The waves carry energy but there is no transport of matter.

Therearetwotypesofwaves;

1. MechanicalorElasticwaves
2. Electromagneticwaves

Mechanicalwaves

Those waveswhich are produced due to repeated periodic motion ofmediumparticles are called mechanical or elastic waves. Theyneedamaterial medium for their generation and propagation. For example sound waves, water waves are mechanical in nature.

Electromagneticwave(Light)

The wave which travels in form of varying electric and magnetic fields mutually perpendicular to each other and also perpendicular to direction of propagation of wave. They do not need material medium for their propagation. For example, light waves, heat radiations,radio waves, X-rays are electromagnetic waves.

The propagation of disturbance through a medium due to repeated periodic motionof medium particlesis called wave motion.

Thecharacteristicsofwavemotionare:

1. Thewavetravelsforwardbuttheparticlesvibrateonlyabouttheirmeanposition.
2. Thevelocityofpropagationistherateatwhichthedisturbancetravelsthroughthe medium.

3. The velocity ofthewave dependson thetype ofwave (light, sound)and type of medium (air, water, or metal).
4. Thevelocityofwavesisdifferentfromthevelocityofparticles.
5. Thereisregularphasedifferencebetweenparticlesofwave.

TypesofWaveMotion: Therearetwotypesofwavemotion;

a) Transversewavemotion
b) Longitudinalwave motion

a) **Transversewavemotion**

When the particles of the medium vibrate perpendicular to the direction of propagation of wave the wave motion is called transverse wave motion. A transverse wave motion is shown in Fig. 7.1. A transversewave consists of onecrest andonetrough that makes onecycle. The distance between two consecutive crests or two consecutive troughs is called wave length. The farthest point in positive direction is called crest and that in negative direction is called trough.

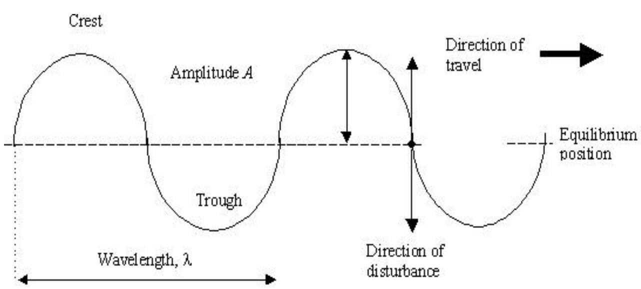


Fig.7.1

Examples are wave produced by a stretched string,light waves, waves produced on surfaceof water etc.

b) **LongitudinalWaves**

When the particles of medium vibrate parallel to the direction of propagation ofwave the wave motion is called longitudinal wave motion. A longitudinal wave travels in the form of compressions and rarefactions as shown in the Fig. 7.2. The part of medium wheredistance between medium particles is less than their normal distance is called compression and the portion where distance is more than their normal distance is called rarefaction. One cycle consist of one complete compression and one complete rarefaction. The distance between two consecutive compressions and rarefaction is called wave length.

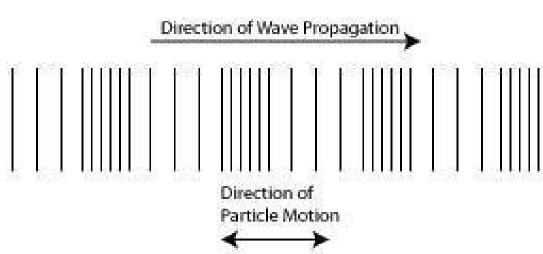


Fig.7.2

Mostfamiliarexample oflongitudinalwavesissoundwaves.Soundwavescan travelin medium such as solids, liquids and gases.

Themainpointsofdifferencebetweentransverseandlongitudinalwavesarelistedbelow:

S.No.	TransverseWaves	LongitudinalWaves
1.	Theparticlesofthemediumvibrate perpendiculartothedirectionof propagationofwave	Theparticlesofmediumvibrateparallel tothedirectionofpropagationofwave
2.	Thewavetravelsinformofcrestsand troughs	The wavetravelsinformof compressionsandrarefactions.
3.	Thereisnochangeindensityofthe medium.	These waves producechangeindensity ofthemedium.
4.	Thesewaves canbepolarised.	Thesewavescannotbepolarised.
5.	Electromagneticwaves,wavetravelling on stretched string,lightwavesarethe examples.	Sound waves, pressure waves,musical waves areitsexamples.

TermsCharacterizingWaveMotion:

Variousparametersusedtocharacterizeawavemotionaredefinedbelow.

Displacement:*Thedistanceofaparticlefromitsmeanposition,atanyinstantis called displacement.*

Amplitude:*Itis themaximumdisplacementoftheparticlefromits meanpositionof rest.*

Wavelength:*Itisthedistancetravelledbythewaveinthetimeinwhichtheparticle of the medium completes one vibration.*

Itisdenoted byλandmeasured inmetres. The distance AB orDE in figure 7.3isequalto one wave length.

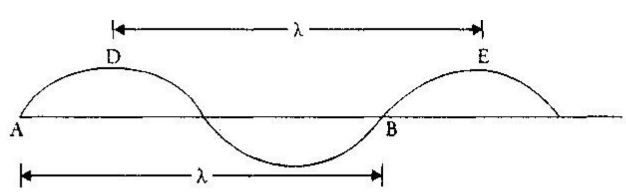


Fig.7.3

Timeperiod:*It isdefinedasthetimetakenbya wavetocompleteonevibrationor one cycle. It is denoted by (T) and S.I. unit is second.*

Frequency:*Thenumberofvibrationsmadebyawaveinonesecondiscalledfrequency. Itcanalsobewrittenasreciprocaloftimeperiod(ν=1/T).*

It is represented by n or ν (nu) and units are Hertz (Hz), Kilo Hertz (KHz), Mega Hertz (MHz) ...etc.

Wave Velocity: *The distance travelled by the wave per unit time is defined as wave velocity. It is denoted as (V) and measured in m/s.*

Phase: Phase of a vibrating particle tells the position of a particle at that instant. It is measured by the fraction of angle or time elapsed by wave at any instant since the particle has **crossed its mean position in positive direction. It is denoted by θ** and unit is radian.

Phase difference: The difference in angle or time elapsed between two particles at any instant. It is calculated by the formula

$$\text{Phase difference} = \frac{2\pi}{\lambda} \times \text{path difference}$$

Relation between Wave velocity, Wavelength and Frequency

Wave velocity is the distance travelled by a wave in one time period.

$$V = \frac{Distance}{Time} = \frac{\lambda}{T}$$

and frequency is reciprocal of time period i.e.

$$\nu = \frac{1}{T}$$

Thus $$V = \nu\lambda$$

The relation holds for both transverse and longitudinal waves.

Numerical 1: A radio station broadcasts at a frequency of 15 MHz. The velocity of transmitted waves is 3×10^8 m/s. What is the wavelength of transmitted waves?

Solution: Given, frequency (ν) = 15 MHz = 15×10^6 Hz, Velocity of waves (V) = 3×10^8 m/s

Using relation; $V = \nu\lambda$

we get wavelength $(\lambda) = \frac{V}{\nu} = \frac{3\times10^8}{15\times10^6} = 20\text{m}$

Numerical 2: A tuning fork of frequency 512 Hz makes 24 vibrations in air. If velocity of sound in air is 340 m/s, how far does sound travel in air?

Solution: Here, frequency (ν) = 512 Hz and velocity = 340 m/s Using the relation $V = \nu\lambda$, we get

Wavelength $(\lambda) = \frac{V}{\nu} = \frac{340}{512} = 0.664\text{m}$

Therefore, distance in 24 vibrations = $24\times\lambda = 24\times0.664\text{m} = 15.94\text{m}$

7.2 FREE,FORCEDANDRESONANTVIBRATIONS

Vibrations

A motion in which the object moves to and fro about a fixed mean position is called oscillatory motion (vibration). All oscillatory motion needs to be periodic.The motion in which the object repeats its path aftera fixed regular interval of time is called periodic motion. For example, motion of hands of clock, motion of spring mass system, simple pendulum, cantilever, rim of cycle wheel etc.

Whenever there are vibrations, there is transfer of energy which makes a wave. An understanding of vibrations and waves is required to understandour physical world. We see around us because of light waves and we hear the world around us becauseof sound waves.

TypesofVibrations:Therearethreetypesofvibrations:free, forcedandresonant.

1) **Free Vibrations:** A force can set a resting object into motion. But when the force is a short-lived or momentary, it only begins the motion. The object moves back and forth, repeating the motion over and again.

   Whenabodyissetintovibrationsandisallowedtovibratefreelyunderthe influence of its own elastic forces such vibrations are called free vibrations.

   Thefrequencyofvibrationiscallednaturalfrequency. Examplesarevibrationsof simple pendulum, cantilever, loaded beam etc.

Freevibrationscanalsobedividedintwoclasses;dampedandundampedvibrations.

a) **Damped Vibrations**: In case of free vibrations, the extent of displacement from the equilibrium position reduces with time. This is because the force that started the motion is a momentary force and thevibrations ultimately cease. Theobject is said to experience damping. Thus when the amplitude of vibrations goes on decreasing with time and finally the vibrations stop after some time then such vibrations are called damped vibrations as shown in Fig.7.4. For example vibrations of cantilever, loaded beam, spring mass system etc. Damping is the tendency of a vibrating object to lose or to dissipate its energy over time. The mechanical energy of the object is lost to other objects. Without a sustained forced vibration, the back and forth motion of the object eventually ceases as energy is dissipated to other objects.

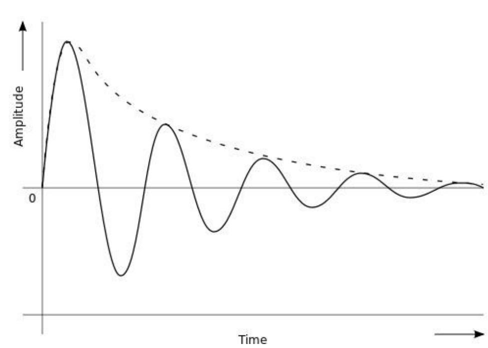


Fig.7.4.Damped vibrations

b) **UndampedVibrations**: If the amplitude of vibrations remains constant and the vibrations continue for infinite time then such vibrations are called undamped vibrations as shown in Fig. 7.5. For example vibrations of simple pendulum in a closed glass box.

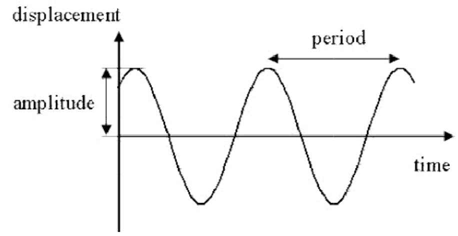


Fig.7.5.Undamped vibrations

2) **ForcedVibrations**:Avibratingobjectnaturallylosesenergywithtime.Itmust continuously be put back into the vibrations through a force in order to sustain the vibration. A sustained input of energy would be required to keep the back and forth motion going. Thus*when a periodic force is used to maintain the vibrations of an object then such vibrations are called forced vibrations*. For example swing of a child.

3) **Resonant Vibrations**: *It is a special type of forced vibration in whichthe frequency of applied force matches with natural frequency of an object.* In this situation resonance occursandtheamplitudeofvibrationsincreaseslargely. Forexampletuning of radio set, swing of a child.

(a) Tuning of a radio set: There are many stations sending radio waves of various frequencies causing forced oscillations in the circuit of receiver. When the frequency of tuner equals thatofwavesfrom particular broadcasting station, theresonance takes place and hence we can hear only that station, whose amplitude is increased.

(b) Another example is swing of a child, which acts as a pendulum. The force with a frequency that matches with the natural frequency of the swing (its resonant frequency) makes the swing go higher and higher (maximum amplitude), while attempts to push the swing at a faster or slower rate produce smaller amplitude. Thisis due to the fact that swing absorbs maximum energy when the force matches withnatural frequency of swing.

Resonance occurs widely in nature. Some sounds we hear, like when hard objects of metal, glass, or wood are struck, are caused by brief resonant vibrations in the object. Electromagnetic waves are produced by resonance on an atomic scale. Other examplesare the balance wheel in a mechanical watch, tidal resonance, acoustic resonances of musical instruments, production of coherent light by optical resonance in a laser etc.

7.3 SIMPLEHARMONICMOTION(SHM)

It is a special type of motion in which the restoring force is directly proportional to displacement from the mean position and opposes its increase.Applying Newton's second law of motion (force = mass× acceleration), it can be stated as ***a periodic motion in which the accelerationisdirectlyproportionaltodisplacementandisalwaysdirected towards mean position***.

In other words, if F is the restoring force and 'y' is the displacement from the mean position, then

$$F = -K y \quad \text{or} \quad a = -\frac{K}{m} y$$

The negative sign indicates that F opposes increase in y and K is constant of proportionality, called force constant. In such motion displacement varies harmonically with time and can be represented in terms of harmonic functions i.e. **sinθ**, **cosθ** such as

$$y(t) = A\sin\omega t \text{ or } A\cos\omega t \qquad (\theta = \omega t)$$

Here A is the amplitude of SHM and is the ***maximum value of displacement from the mean position*** and ω is angular frequency.

Characteristics of SHM:

- The motion should be periodic.
- Force causing the motion is directed toward the equilibrium point (minus sign).
- Acceleration produced is directly proportional to the displacement from equilibrium.

Under the influence of a restoring force (F), a body acquires a velocity $\left(\frac{dy}{dt}\right)$ and hence an acceleration $\left(\frac{d^2y}{dt^2}\right)$. This can be written as

$$\text{Acceleration} = -\frac{K}{m} \times y$$

or

$$\frac{d^2y}{dt^2} = -\omega^2 y \quad ; \quad \omega = \sqrt{\frac{K}{m}}$$

Term ω is called angular frequency which is 2π times the frequency (ν). Frequency (ν) is measured in cycles per second (cps) or Hertz (Hz) and ω in radians/sec.

$$\omega = 2\pi\nu = \frac{2\pi}{T}$$

T is the time period of the motion (smallest time interval after which a motion repeats itself) and is given by

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{K}}$$

Examples of SHM are; motion of simple pendulum, cantilever, mass-spring system, swing etc.

7.4 CANTILEVER

A metallic beam fixed at one end and free to vibrate at other end is called cantilever. The normal configuration of a cantilever is shown in Fig. 7.6.

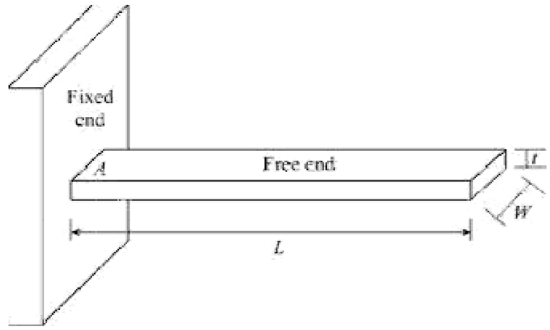


Fig.7.6ACantilever

When it is loaded at free end it vibrates and its edge performs simple harmonic motion. The time taken to complete one vibration is called time period.

Thetimeperiodisgivenby

$$T=2\pi\sqrt{\frac{p}{g}}$$

Where p is the depression of beam (displacement of beam from its unloaded position) and gis acceleration due to gravity.

7.5 SOUNDWAVES

These are mechanical waves and need medium for their propagation. Sound waves also called pressure waves can be transmitted through solid, liquid or gas.There are three frequency ranges in which sound is categorised:

a) **Audible:**Thesoundwavesbetweenfrequencies20Hzto20 kHzisaudibleto human ears and is called audible range.
b) **Infrasonic:** Sound waves below frequency 20Hz are called infrasonic and are inaudible to human ears. A number of animals produce and use sounds in the infrasonic range. For example elephant, whales, rhinos etc.
c) **Ultrasonic:** The sound waves with frequency above 20 kHz are called ultrasonic. Batscommunicatethroughultrasonicwaves.Theyarealsoinaudibletohumanears.

Propertiesofsoundwavesare:-

1. Soundwavesarelongitudinalmechanicalwaves.
2. Theyneedmaterialmediumfortheirgenerationandpropagation.
3. Theycannottraversethroughvacuumsotheirvelocityinvacuumiszero.
4. TheirvelocityinairatNTPis332m/sanditincreaseswithriseintemperature.
5. Soundwavestravelfasterinsolidsthaninliquidsthaningasses.
6. Theyshowthephenomenaofreflection,transmission,diffractionetc.

7.6 ACOUSTICSOFBUILDINGS

The branch of physics that deals with study of audible sound including their generation, propagation and properties is called acoustics.

Acoustics of buildings: It deals with construction of public halls, auditoriums, cinema halls etc. for best sound effects.

Generation of Audible Sound: Any object that can produce longitudinal mechanical waves of frequency between 20 Hz to 20 KHz generates audible sound. For example, musical instruments, vibrating fork, human throat (vocal chord) etc.

Propagation of Audible Sound: Audible sound propagates in material medium only. Its velocityislowestinairandincreaseswithincreaseindensityofthemedium. Ittravelsfastest in metals. While travelling in one medium if it meets another medium it gets divided into three parts;reflected part, absorbed part and transmitted part.

CoefficientofAbsorptionofSound:

The ratio of sound energy absorbed by a surface to the total sound incident on a surface is called coefficient of absorption or simply absorption coefficient of sound. It is denoted by **'a'** andits SI unit isOWU (Openwindow unit). Its value is maximum (=1) for an open window.

$$a = \frac{\text{absorbedsoundenergybyasurface}}{\text{Totalsoundenergyincidentonthesurface}}$$

TypesofAudibleSound:Twotypesofaudiblesoundaremusicalsoundand noise.

Musical Sound**:** The sound that produces pleasant effect on our ears is called musical sound.It is a single sound or multiple sounds having same frequency, wavelength and meeting in same phase.

Noise: Thesounds thatproduce unpleasant effect on ourears arecalled noise. It hasirregular amplitude with time. It is generally a combination of multiple sounds of different frequency, wavelength and meeting in different phases.

Reverberation:

Itisthepersistenceofsoundafterthesourcehasstoppedemittingsounddueto reflection from multiple surfaces.

ReverberationTime:

The time up to which a sound persists in a hall or room after the sourcehas stoppedemitting it is called reverberation time.

Standard reverberation time (Sabine's formula): Reverberation time is the time taken by the sound intensity to drop by 60 dB or reduce to its one millionth parts. An American scientist W. C. Sabine developed an equation for calculating the reverberation time as:

$$T = \frac{0.16V}{\sum a \times S}$$

where V is the volume of the hall in m^3, a is the average absorption coefficient of room surfaces and S is total surface area of room in m^2.

Here $\sum aS = a_1 s_1 + a_2 s_2 + a_2 s_3 + ...$

where a_1, a_2, a_3 etc. are absorption coefficientsofdifferentobjectsin halland s_1, s_2, $s_3$etc.are their surface areas.

Echo:

Therepetitionoforiginalsoundbyreflectionfromasurfaceiscalledecho.Theecho is produced if the reflected sound reaches our ears after 1/10 of a second. It is different from reverberation as echo is identified as repeated sound due to a time gap of at least 1/10 of a second.

Thedistance'd'ofreflector/obstaclecausingechoisgiven by

$$d = \frac{V.t}{2}$$

where'V'isvelocityofsoundand't'istimetakenbyreflectedsoundtoreachourears.

Theminimumdistanceofobstacletoproduceechothusisgivenas s =

$$\{332\times (1/10)\}/2 = 16.6 \text{ m/s}$$

Thus, the obstacle must be placed at a minimum distance of 16.6m from the source toproduce echo.

MethodstoControlReverberationtime:

Tocontrolreverberationtimethesimplestwayistoincreaseabsorptioninthehall. Themethodstocontrolreverberationare:

1. *Provide few open windows in hall*-Open windows are good absorbers of sound and the reverberation time can be controlled by adjusting the number of open windows in the hall.
2. *Coverthefloorwithcarpets*-The carpetsare also good absorbersofsound which help in reducing the reverberation time in the hall.
3. *Curtains*-The useofheavyfolded curtainson doorsandwindowsallowsto control the reverberation time.
4. *Coverthewalls*-Coveringthewallswithabsorbingmaterialslikefibreorasbestos sheetsetc. help in reducing reverberation time.

5. *Providefalseceiling*-Falseceilingismadeofsoundabsorbingmaterialswhich reduces the reverberation in a hall.
6. *Usingupholsteredcushionedseatsinhall*- The seats in the empty hall would also absorb the sound if they are made of good absorbing cushioned material and turn up when no one is sitting on them.
7. *Agoodnumberofaudience*increasestheabsorptionof hall.

7.7 ULTRASONICS

Thesoundwaveshaving frequencymorethan20 kHzarecalledultrasonics. Their characteristics are:

i. Theyarehighfrequencyandhigh energywaves.
ii. Iftheyarepassedthroughaliquiditisshakenviolently.
iii. Theyworkascatalystforchemicalreactions.
iv. Theycanbesentintheformofnarrowbeamtolong distanceswithoutlossof energy.
v. Travellinginonemediumiftheymeetanother, theyreturnbackinsamemediumat 180 degree.
vi. Justlikeordinarysoundwaves,ultrasonicwavesgetreflected,refractedandabsorbed.
vii. Theyproduceintenseheatingeffectwhenpassedthroughasubstance.

Production of Ultrasonic: The natural producer of ultrasonicsis'Bat'. Another simple method to produce low frequency ultrasonics is 'Galton's whistle'. Two types of oscillators are used to produce ultrasonic sounds:Magnetostriction oscillator, Piezo electric oscillator.

Applications of Ultrasonic: Ultrasonic waves are used in various fields like; medical for ultrasound, navigation for various purposes, engineering for drilling, cleaning, flaw detection etc. Some important applications of ultrasonic are described below:

1) **Drilling:** Ultrasonic is high frequency and high energy wave, so they can be used in applications involving high amount of energy. They can be used tomake a drill even in hardestmaterialofworld i.e. Diamond. Forthisa toolbitis attached at lower end of magneto-striction oscillator. The sheet to be drilled is kept below the tool bit. It is driven bya magneto-strictionoscillator that creates the vibrations. When oscillator is switched on the tool bit moves up and down that produces enough strain to make a drill in the sheet. ThesetupofdrillingisshowninFig.7.7.

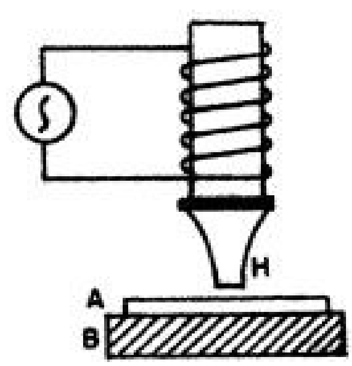


Fig.7.7 Ultrasonicdrilling

2) **Ultrasonic welding (cold welding):**The setup is shown in Fig. 7.8. Cold welding means welding without involvement of heat which is possible only with ultrasonics. A hammeris attached at lower end of magnetostriction oscillator. The sheets to be welded are kept below hammer. When oscillator is switched on hammer strikes the sheets frequently. In case of resonance the molecules of both sheets enter in each other due to high amplitude

and welding is performed without involvement of heat. The interfaceofthetwopartsisspeciallydesignedtoconcentrate the energy for maximum weld strength.

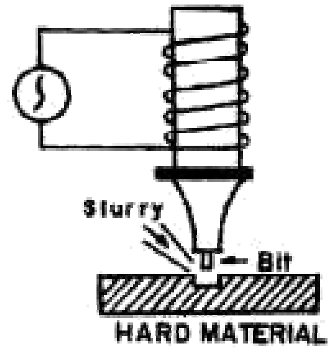


Fig.7.8 Coldwelding

3) **SONAR**:SONARisatechniquewhichstandsforSound Navigation and Ranging. It uses ultrasonic for the detection andidentificationofunderwater objects.Apowerfulbeam of ultrasonic is sent in the suspected direction in water. By noting the time interval between the emission and receipt of beam after reflection, the distance of the object can be easily calculated.Measuring the time interval (t) between the transmitted pulses and the received pulse, the distance between the transmitter and the remote object is determined using the formula

$$d=V\times\frac{t}{2}$$

whereV is the velocity of sound in sea water. Thesame principle is used to find the depth of the sea as shown in Fig. 7.9.

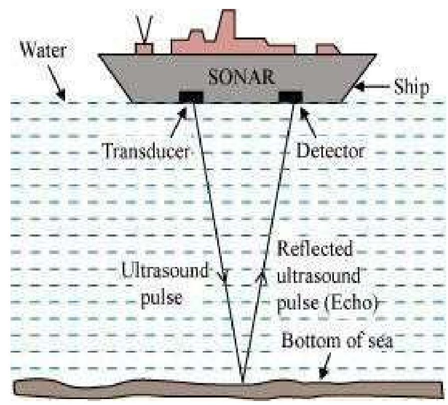


Fig.7.9 Soundnavigationandranging

Numerical 3. An ultrasonic scanner travelling with a speed of 1.5km/s in a tissue operating underafrequencyof4.1MHz. Whatisthewavelengthofsoundinthetissue?

Solution:

Given, Velocity (V) =1.5km/s=

1.5×1000=1500m/sFrequency(ν)=4.1MHz=4.1×10^{6}Hz

Usingtherelation;V=νλwecanget

Wavelength, $\lambda=\frac{V}{\nu}=\frac{1500}{4.1\times10^{6}}=3.65\times10^{-4}$m=36.5mm

Numerical4. Amanhearshissoundagain afterreflection fromacliffafter1 second.Ifthe velocity of sound is 330m/s, find the distance of cliff from the man.

Solution: Given

Velocityofsound,V=330m/s

Timeafterwhichsoundisheard,t=1.0s

Letdbethedistanceofcliffromman.

Totaldistancetravelledbysoundingoingandcomingbackfromcliff=2d

Thus, $2d = V \times t = 330 \times 1 = 330m$ $d = \frac{330}{2} = 165m$

******

UNIT -2

(OPTICS)

Introduction

Optics is the branch of physics which deals with the study of behavior and properties of light. Light is an electromagnetic wave having transverse nature. Although light has dual nature; particle as well as wave, classical approach considers only wave nature. The wave nature is furthersimplified in geometric optics, where light is treated as a ray which travels in straight line. Ray optics model includes wave effects like diffraction, interference etc. Quantum optics deals with application of light considered as particles (called photons) to the optical systems. The phenomena of photoelectric effect, X-rays and lasers are explained inthe quantum optics (particle nature of light).

RayOptics(Geometricoptics)

Geometrical optics describes the propagation of light in terms of rays. The assumptionsof geometrical optics are:

- Lighttravelsinstraight-linepaths.
- Itbends, orsplitintopart,attheinterfacebetweentwodifferentmedia.
- Itfollowscurvedpathsinamediumwhererefractiveindexchanges.
- Itmaybereflected,absorbedortransmitted.

8.1 REFLECTIONANDREFRACTIONOFLIGHT

ReflectionofLight

Reflectionisthebouncingbackoflight at aninterfacebetweentwodifferentmedia.

Glassy surfaces such as mirrors exhibit specular reflection. This allows for production of reflected images that can be associated with real or virtual location in space. Figure 8.1 depicts the phenomenon of reflectionfromaglass-airinterface.POisthelightrayincidentona glass mirror at an angle θ_i(angle of incident) and OQ is the light ray reflected from the surface at an angle θ_r (angle of reflection).

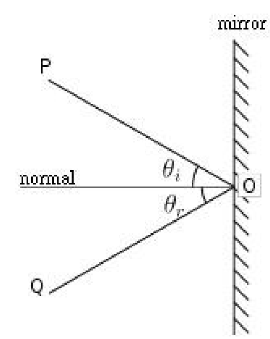


Fig.8.1 Reflectionoflight

<u>Lawsofreflection</u>:

1)Theincidentandreflectedrayandthenormal,alllieinsame plane,and

2) Theanglebetweentheincidentray andthenormalisthesameasthatbetweenthe reflected ray and the normal i.e. $\theta_i = \theta_r$

Refractionoflight

Whena light ray passes fromone transparentmedium toanother, it gets deviated from its originalpath while crossing the interfaceoftwomedia. *Thephenomenaofbendingoflight rays fromtheiroriginalpathwhilepassingfromonemediumtoanotheriscalledrefraction.*

- Whenlighttravelsfromararermediumtodensermedium, itbendstowardsthe normal.
- Whenlighttravelsfromadensermediumtorarermedium, itbendsawayfromthe normal.

It happens when light travels through medium that hasa changing index of refraction. Refraction occurs dueto change in speed of light as it enters a differentmedia. Figure 8.2 describe the occurrence of refraction at an interface.

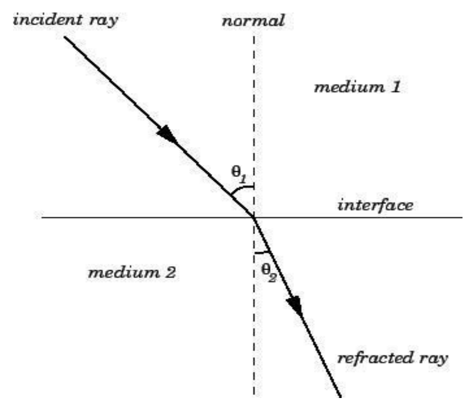


Fig.8.2 Refractionoflight

<u>Lawsofrefraction</u>**:**

1) Theincidentray, therefractedrayandthenormal all lie in the same plane.
2) Theratioofsineofincidenceangle(**θ**1)tothesine ofrefracted angle (**θ**2)isa constantforthatpairofmedia and is equal to the **refractive index** of that media. This is alsoknownas**Snell'slaw**

$${}^1\mu_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{\sin i}{\sin r}$$

Where 'i'isthe angle ofincidence and 'r' isthe angleofrefraction and ${}^1\mu_2$isthe refractive index of medium 2 w.r.t. medium 1.If medium 1 is vacuum then,

$$\mu = \frac{\sin\theta_1}{\sin\theta_2}$$

Whenlighttravelsfromair(vacuum)toamediumthenrefractiveindexofthemediumcan be written as

$$\mu = \frac{c}{v}$$

where c is the velocity of light in air (vacuum) and v is the velocity of light in the medium. For example, the refractive index of water is 1.333, meaning that light travels 1.333 times slower in the water than in vacuum. Thus, the refractive index of a material is adimensionless number that describes how light propagates through that medium.

The Snell’s law is used to find the deflection of light rays when they pass through different media. It is used to produce dispersion spectra through a prism since light rayhaving different frequencies have slightly different refractive index in most materials.

The refractive index of some material varies with position and time. In such medium, light travels in curved path rather than straight lines. This is responsible for mirage effect observed on hot day due to different refractive index of air that causes light to bend, creating specular reflections in distance(as if water on the surface of a pool). The material having varying refractive index is useful in modern photocopy and scanning technologies.

LensandLensFormula

Lens is an optical device based on phenomenon of refraction. A lens is a transparent medium bounded by two refracting surfaces. It can produce two types of rays- convergingand diverging rays. Convex lens is converging while concave lens is diverging.

Termsrelatedinstudyof lenses:

1. **Centreof curvature**:Thecenterofcurvatureofalensisthecentreofspherewhich forms a part of the spherical surface of the lens.
2. **Radius of curvature**: The radius of the sphere of the spherical surface of lens is called radius of curvature. It is the distance of the vertex of the lens from the center of curvature.
3. **Principal axis**: The principal axis of a lens is an imaginary line that is perpendicular to the vertical axis of the lens. Principal focus of the lens lies on this axis. All rays parallel to the principal axis that are incident on the lens, would either converge (if lens is converging) to, or diverge (if the lens is diverging) from, the principal focus.
4. **Opticalcentre**:Opticalcentreisthecentreofthelenslyingontheprincipalaxis. Ifa light ray passes through optical centre, it goes undeviated.
5. **Principal focus**: When the parallel rays are incident on a lens, they either converge at a pointorappearto divergefromapointon theprincipalaxis, thatpoint iscalledprincipal focus.
6. **Focal length (f)**: The distance of principal focus from the optical centre is called focal length. In other words, focal length is equal to the image distance when the object is at infinity.
7. **Image**: If two or more rays passing from a point gets refracted through a lens and converges or appears to diverge to a point then that point is called the image of firstpoint. The image can be real or virtual. In real image, rays actually meet at the second point, while in virtual image; the rays appear to diverge from the second point.

Lensformula

Thefocallength(f)ofaconvexlensisrelatedtoobjectdistance(u)andimagedistance(v)as

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$ ⇒Thisiscalledlensformula.

Thelinearmagnificationofalensisgivenby;m= $\frac{v}{u}$ andholdsforbothconvexand concave lenses and for real as well as virtual images.

Poweroflens

Power of a lens is defined as the reciprocal of the focal length measured in metres.The unit of power of lens is m^{-1} which is called ***dioptre***indicated by symbol **'**D**'**. In other words, one dioptre is the power of a lens of one metre focal length.

$$P = \frac{1}{f} \quad \text{(fistakeninmeters)}$$

Thepowerofaconvexlensispositiveandthatofconcavelensisnegative. Iftwo lensesare combined (placed in contact), the focal length of the combination is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Thusthepowerofcombinationbecomessumofpowerofindividuallenses.i.e.

$$P = P_1 + P_2$$

8.2 TOTALINTERNALREFLECTION(TIR)

When light is reflected into a denser medium from an interface of the denser and a rarer medium, and there is no refracted light, the phenomenon is known as total internal reflection.

ThereаretwoessentialconditionsforTIR:

1. Thelightshouldtravelfromadensermediumtoararermedium.
2. Theangleofincidenceinthedensermediumshouldbegreaterthanthecriticalangle.

The largest possible angle of incidence at the interface which results in a refracted ray is called the *critical angle*. At the critical angle of incidence, the refracted ray travels along the boundary between the two media i.e. the angle of refraction becomes90^0.Forangleofincidence greater than critical angle light is totally reflected as shown in Fig. 8.3.

The criticalangle for a materialdepends upon the refractive index.Higher the refractiveindex,thelowerthecritical angle.Itcanbecalculatedusingthe followingformula:

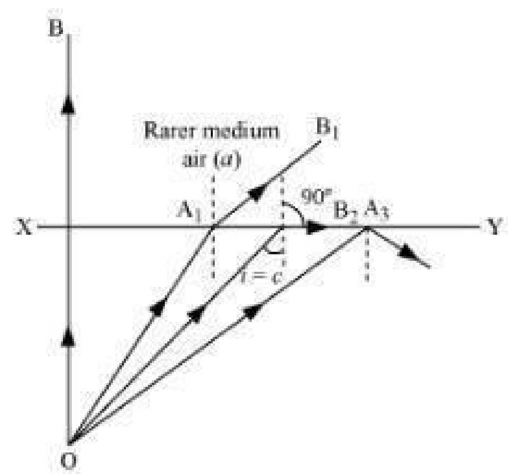


Fig.8.3 Totalinternalreflection

$$\sin\theta_C = \frac{1}{\mu}$$

where θ_C is the critical angle and μ is the refractive index.

ApplicationsofTIR

1. TIR isthebasicprincipleofopticalfiberswhichareusedastransmissionmediain sending telecommunication signals and images in endoscopes.
2. AutomotiverainsensorsworkontheprincipleofTIR,whichcontrolautomatic windscreen wipers.
3. Prismsinbinocularsalsoformerectimagesbasedontotalinternalreflection.
4. Somemulti-touchscreensalsouseTIRtopickupmultipletargets.
5. Opticalfingerprintingdevicesusedtorecordfingerprintswithouttheuseofinkare also based on TIR.
6. Thebrightshiningofdiamondsisalsoaresultoftotalinternalreflection.

8.3 OPTICALINSTRUMENTS

An optical instrument is a device which is used to view the objects. The eye is basic and essential optical system. In addition to it, other instruments are devised to increase the range a human's viewing ability. The optical instruments are an aid to the eye. They consistof an arrangement of lenses, prisms or mirrors which enables to see better than what we can see with the naked eye.Thesecanbe of two types:

1. Whentherealimageisformedonscreenasincaseofphotographiccamera, overhead projector etc.
2. Whenavirtualimageisformedandcanbeseendirectlywitheyeasintelescopes, microscopes, binoculars etc.

In the presentscope,wewillstudy abouttwoopticalinstruments;microscopesand telescopes.

a) Microscope: *Amicroscope is an optical instrument which enables us to see magnified image of objects that are too small to be seen by the naked eye*. A microscopic object is invisible to the eye unless aided by a microscope. Fig.8.4 shows the view of a microscope.

Therearetwotypesofmicroscope:

1. **Simple microscope**. It is also known as magnifying glass. It is made of only one convex lens andthe object is so adjusted before the focal point that the image is formed at least distance of distinct vision.
2. **Compoundmicroscope**.Themagnificationproduced byasimplemicroscopeissmallandisonly governed

Fig.8.4 Amicroscope

bythefocallengthoflens.Toproducelargemagnification, acompoundmicroscopeis usedinwhichmagnificationisobtainedintwostagesbytheuseoftwoconvex lenses.

b) **Telescope:**A telescopeisanopticalinstrumentwhichisusedtoseedistantobjectsclearly. There are three types of telescopes:

1. **Astronomical** (to see astronomical objects): It is used to see heavenly objects like stars and planets. The image formed in an astronomical telescope is inverted.

Fig.8.5ATelescope

2. **Terrestrial**(Toseeobjectsonearth):Astronomicaltelescope formsaninvertedimagewhichisnotsuitableto seetheterrestrialobjectslikebuildings,treesetc.For seeing the distant objects lying on earth, the final image should be erect.A terrestrialtelescope (Fig. 8.5)formsan erectimageandmakesuseofthreeconvexlenses.

3. **Galilean**(modificationofterrestrialtelescope):Itisamodifiedversionofterrestrial telescope which also forms erect image but with the use of only two lenses.

8.4 USESOFMICROSCOPEANDTELESCOPE

a) UsesofMicroscope

1. Biologicalscientistsusemicroscopetoseemicroorganismsandtheirbehavior.
2. Doctorsusemicroscopetoseeandexaminebloodcellsandbacteria.
3. Forensicscienceexpertsusemicroscopetoanalyzetheevidencesofcrimes.
4. Jewelersandwatchmakersuseittoseethedetailsofpartstheyareworking with.
5. Environmentalistusesittotestthesoilandwatersamplesforpresenceofpollutants.
6. Geologistusesittotestthecompositionofdifferenttypesofrocks.
7. Theseareusedinvariousexperimentsinschoolsandcolleges.

b) UsesofTelescope

1. Astronomicalobjectsareseenbyusingtelescopeby astronomers.
2. Theyfounduseinterrestrialapplicationsalso. Theyareusedinlaboratoriesto perform different experiments and finding values of different quantities.
3. Spectrometryusestelescopestofindwavelengthoflightandspectrallinesetc.
4. Itisusedinspyglassesandlongfocuscamera lenses.

Solved Numericals

Numerical 1. A lens is having power of +4D. What is its focal length?

Solution: Given, Power (P) = +4D

We know that $P = \frac{1}{f}$

Therefore, $4 = \frac{1}{f}$ or $f = \frac{1}{4}$ m = 0.25 m = 25 cm

Thus, focal length of lens is 25 cm

Numerical 2. An object is kept at distance of 30 cm from a convex lens of focal length 0.2 m. Find the position of the image formed.

Solution: Given, distance of object, u = -30 cm = -0.3 m, and f = 0.2 m

The lens formula is $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

or

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{0.2} + \frac{1}{(-0.3)} = 5 - 3.33 = 1.67$$

$$v = \frac{1}{1.67} = 0.598 = 0.6\text{ m} = 60\text{ cm}$$

Numerical 3. A light wave has wavelength of 600 nm in vacuum. What is the wavelength of the light as it travels through water (index of refraction = 1.33)?

Solution:

Given, wavelength (λ) = 600 nm = 600×10^{-9} m (1 nm = 10^{-9} m).

The wavelength of light that travels through a medium of refractive index n changes by expression

$$\lambda_n = \frac{\lambda}{n} = \frac{600 \times 10^{-9}}{1.33} = 451 \times 10^{-9}\text{ m} = 451\text{ nm}$$

******

UNIT-3

ELECTROSTATICS

Thebranchofphysicswhichdealswiththestudyofchargesatrestiscalled electrostatics.

9.1. ELECTRICCHARGE

ElectricCharge:itisthephysicalproperty ofmatterthatcausesitto experienceforcewhen placed in an electromagnetic field. There are two types of charges.

(1) **Positivecharge**:e.g.Proton,Alphaparticle
(2) **Negativecharge**:e.g.Electron,etc.

Chargeonelectronissmallestunitofcharge.

SIunitofchargeiscoulomb (C).

Charge onElectron=-1.6×10^{-19}C
ChargeonProton=$+1.6\times10^{-19}$C

Likechargesrepeleachotherandunlikechargesattracteachother.i.e.

+ve	+ve	Repel
-ve	-ve	Repel
+ve	-ve	Attract
-ve	+ve	Attract

ConservationofCharge

Charge conservation is the principle that total electric charge in an isolated system never changes. It alwaysremains constant. This also means that no net charge can be created or destroyed. When an atom is ionized, equal amounts of positive and negative charges are produced. Hence the algebraic sum of charges before and after remains the same.

QuantizationofCharges

Charge quantization is the principle that the charge of any object is an integermultiple of the elementary charge (e). Thus, an object's charge can be exactly 0*e*, or exactly1 *e*, **−1** *e*, 2 *e*, etc.,

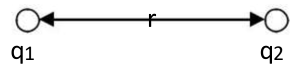
9.2. COULOMB LAW OF ELECTROSTATICS

Itstatesthatforceofinteractionbetweentwopointchargesis

(i) Directlyproportionaltomagnitudeofchargesand

(ii) Inverselyproportionaltothesquareofthedistancebetween them.

LetFisforce betweentwochargesq1and q2.Then



$$F \alpha q_1 q_2$$

$$F \alpha \frac{1}{r^2}$$

$$\Rightarrow F \alpha \frac{q_1 q_2}{r^2} \qquad \text{.........(1)}$$

$$F = K \frac{q_1 q_2}{r^2} \qquad \text{.........(2)}$$

whereKisconstantofproportionalityanditsvalueisgivenas

$$K = \frac{1}{4\pi\epsilon_0} = 9\times10^9 \ \text{Nm}^2/\text{C}^2 \text{(inSIunitssystem)}$$

Nowfromequation(2)

$$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2} \qquad \text{..........(3)}$$

Here ϵ_0 iselectricalpermittivityofvacuum.Itsvalueis $8.854\times10^{-12} N^{-1}m^{-2}C^2$.

Let $q = q_1 = q_2$

r=1m

thenfromequation(3) $F = 9\times10^9$ N

Thus*onecoulombisthatmuchchargewhichproducesaforceof9 ×10^9 N ataunit charge placed at a distance of 1 m.*

Smallerunitsofcharge; milliCoulomb(mC)=10^{-3}C.
microCoulomb(μC)=10^{-6}C.

9.3. ELECTRICFIELD

Itistheareaaroundthechargeinwhichforceofattractionorrepulsioncanbe experiencedbyanothercharge.

Electricfield intensity atpointisdefinedastheforceacting on aunitpositivechargeatthat point.

$$\vec{E} = \frac{\vec{F}}{q_0}$$

- *Aunitpositivechargeisalsocalled as test charge*

Thevalueof$q_0$should beverysmall.ItsSIunitisN/C(NewtonperCoulomb)

ElectricLinesofForce:

Anelectriclineofforceisanimaginarycontinuouslineorcurvedrawninanelectricfield such that tangent to it at any point gives the direction of electric force at that point (Fig. 9.1).

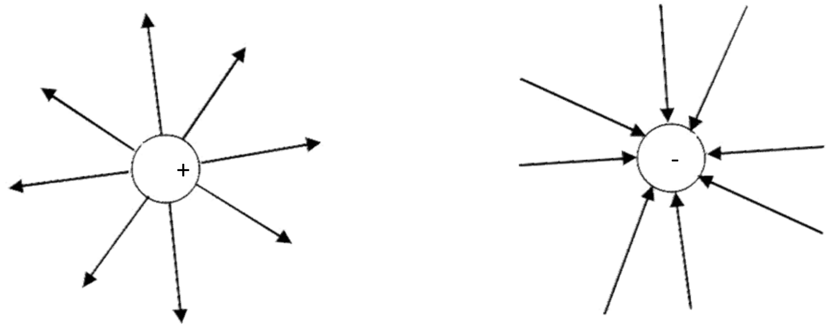


Figure 9.1

Propertiesofelectriclinesofforce

- *Linesofforceoriginatefrom apositivechargeandterminatetoanegative charge.*
- *Thetangenttothelineofforceindicatesthedirectionoftheelectric fieldand electric force.*
- *Electriclinesofforcearealwaysnormaltothesurfaceofchargedbody.*
- *Electriclinesofforcecontractlongitudinallyandexpandlaterally.*
- *Twoelectriclinesofforcecannotintersecteachother.*
- *Twoelectriclinesofforceproceedinginthesamedirectionrepeleachother.*
- *Twoelectriclinesofforceproceedingintheoppositedirectionattracteach other.* *There are no lines of force inside the conductor*

9.4. ELECTRICFLUX

It is the measure of distribution of electric field through a given surface. Electric flux is defined as total number of electric lines of force passing per unit area normal to thesurface. It is denoted byψ (psi).

Considersmallelementaryarea $\vec{ds}$*onaclosedsurfaceS.Electric field* $\vec{E}$ *exitinthe space. If θ is the angle between* $\vec{E}$ *and area vector* $\vec{ds}$ *as then*

$$\psi=\oint \vec{E}.d\vec{S} \text{ iscalled electric flux.}$$

GAUSS'SLAW

Its*tatesthatnetelectricfluxofanelectricfieldoveraclosedsurfaceis equal tothenet chargeenclosedbythesurfacedividedby*$\in_0$*i.e.*

$$\psi=\oint \vec{E}.d\vec{S}$$

$$\psi=\oint_S E\,dS\cos\theta=\frac{q}{\varepsilon_0}$$

Proof: Consideraclosed surface *S* havingachargeqplaced atapoint *O* insideaclosedsurfaceasshowninFig. 9.2. Take a point *P*onthesurfaceand consider a small area *dS*around *P* .

OP=r

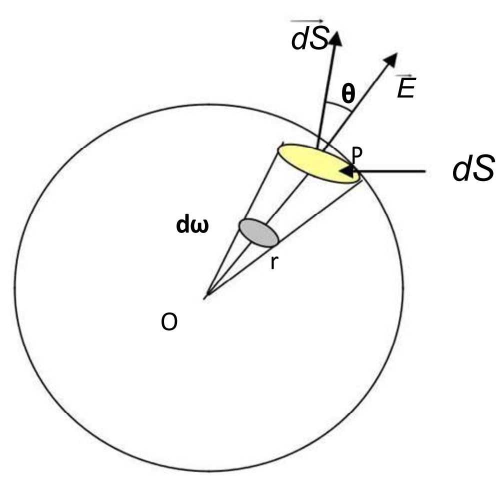


Figure9.2

Then Electric field at P is

$$E = \frac{q}{4\pi\epsilon_0 r^2} \quad \ldots\ldots\ldots\ldots(1)$$

Now electric flux

$$\psi = \oint_S E\,dS\cos\theta$$

Putting value of E we get

$$\psi = \oint_S \frac{q}{4\pi\varepsilon_0 r^2} dS\cos\theta$$

$$\psi = \frac{q}{4\pi\varepsilon_0}\oint_S \frac{dS\cos\theta}{r^2}$$

$$\psi = \frac{q}{4\pi\varepsilon_0}\oint_S d\omega \qquad \because \frac{dS\cos\theta}{r^2} = d\omega$$

$$\psi = \frac{q}{4\pi\varepsilon_0}.4\pi \qquad \because \text{Total Solid angle} = 4\pi$$

$$\psi = \frac{q}{\epsilon_0}$$

Hence, $\psi = \oint_S E\,dS\cos\theta = \frac{q}{\varepsilon_0}$

Applications of Gauss's Law:

Electric field due to a point charge:

Consider a point charge q. We want to find electric field at point P at a distance of r from it. Construct a spherical surface of radius r. This is called as Gaussian surface. Consider small area dS **on the surface. Let θ is angle between** $\vec{E}$ and Area vector as shown in Fig. 9.3.

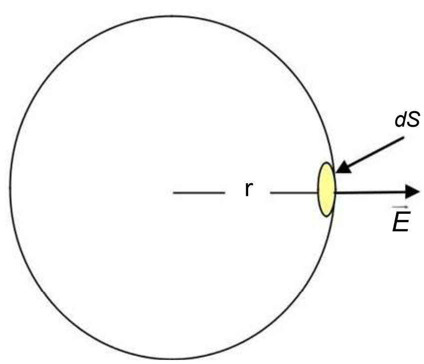


Figure 9.3

Now flux

$$\psi = \oint_S E\,dS\cos\theta = \frac{q}{\varepsilon_0} \qquad (\because \theta = 0)$$

$$E\oint_S dS = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E.4\pi r^2 = \frac{q}{\epsilon_0} \qquad (\because \text{Area of Sphere} = 4\pi r^2)$$

$$\Rightarrow \boxed{E = \frac{q}{4\pi\epsilon_0 r^2}}$$

Thustheelectricintensitydecreaseswithincreaseindistance.

9.5. CAPACITOR

Itisanelectroniccomponentthatstoreselectriccharge.

Capacitance

Theabilityofasystemtostoreanelectriccharge.

Aspotentialisproportionaltocharge

$$V \propto q$$

or $$q \propto V$$

$$q = CV$$

$$C = \frac{q}{V}$$

Unitofcapacitance:Farad(F),microfarad

<u>GroupingofCapacitors</u> Series

Grouping:

A numberofcapacitorsaresaidbeconnectedinseriesif -veplateofonecapacitoris connected to the +ve plate of other capacitor andso on. Inthis grouping, current is same on each capacitor.

Consider3 capacitorsofcapacitancesC_1,C_2,C_3 in series. LetVistotalappliedvoltage. V_1, V_2, V_3 → **voltage drops across C**$_1$, C_2, C_3as shown in fig. 9.4.

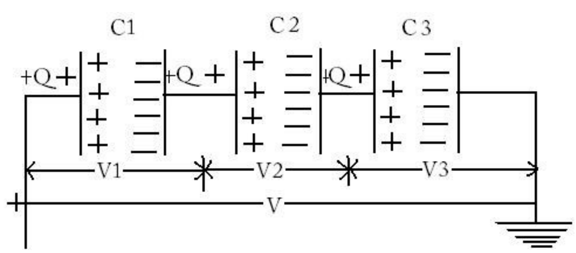


Figure9.4

Then$V=V_1+V_2+V_3$ ------------------------(1)

Now$C=\frac{q}{V} \Rightarrow V=\frac{q}{C}$

So, $V_1=\frac{q}{C_1}, V_2=\frac{q}{C_2}, V_3=\frac{q}{C_3}$

PuttinginEquation(1)

$$\frac{q}{C}=\frac{q}{C_1}+\frac{q}{C_2}+\frac{q}{C_3}$$

$$\frac{q}{C}=q\left(\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}\right)$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Sothetotalcapacitancedecreasesinseriesgrouping.

Thereciprocal oftheequivalentcapacitanceoftwocapacitorsconnectedinseriesis the sum of the reciprocals of the individual capacitances.

ParallelGrouping:

A number of capacitors are said to be connected in parallel if +ve plate of each capacitor is connected to the +ve terminal of battery and –ve plate of each capacitor is connected to the –ve terminal of battery.

Inthisgroupingvoltageacrosseachcapacitorinsame.

Consider3 capacitorsofcapacitancesC, C_2, C_3 connectedin parallelletVisapplied voltage. q_1, q_2, q_3 → charges on capacitors C_1, C_2, C_3 as shown in fig. 9.5

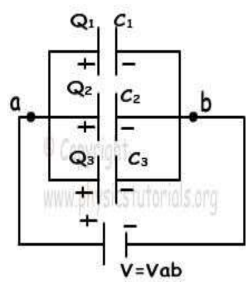


Figure9.5

So

$q=q_1+q_2+q_3$ ------------------------(1)

Now $C=\frac{q}{V}$ or $q=CV$

$\therefore q_1=C_1V$, $q_2= C_2V$, $q_3=C_3V$

Putinequation(1)

$CV= C_1V+C_2V+C_3V$

$CV = (C_1 + C_2 + C_3) V$

$C = C_1 + C_2 + C_3$

Sothetotalcapacitanceincreasesinparallelgrouping.

Theequivalentcapacitanceofcapacitorsconnectedinparallelissumof the individual capacitance.

SolvedNumericals

Example1.Calculatethecoulombforcebetweentwoprotonsseparatedbyadistanceof 1.6×10^{-15}m.

Solution: Given, 2protons;ChargeonProton=1.6×10^{-19}C $q_1 = q_2 = 1.6\times10^{-19}$C

Distance,r=1.6×10^{-15}m

Also $\frac{1}{4\pi\varepsilon_0}=9\times10^9 Nm^2/C^2$

Now $F=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

$$F=\frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{(1.6\times10^{-15})^2}$$

F=90N

Example2.Calculatetheforcebetweenanalphaparticleandaprotonseparatedbydistance of 5.12×10^{-15}m.

Solution: Given,q_1=Chargeonalphaparticle=$2\times1.6\times10^{-19}$C

q_2=Chargeonproton=1.6×10^{-19}C

distance,r = 5.12×10^{-15}m

$\frac{1}{4\pi\varepsilon_o}=9\times10^9 Nm^2/C^2$

Now

$$F=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

$$F=\frac{9\times10^9\times3.2\times10^{-19}\times1.6\times10^{-19}}{(5.12\times10^{-15})^2}$$

F =17.58N

Example3.ThreeCapacitorsofcapacitances3μF,2μF and4μF areconnectedwith each calculate total capacitance (a) In Series grouping (b) Parallel grouping.

Solution: Given,

C_1=3μF, C_2=2μF and C_3=9μF

InSeriesgrouping

$$\frac{1}{C_{tot}}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$$

$$\frac{1}{C_{tot}}=\frac{1}{3}+\frac{1}{2}+\frac{1}{9}$$

$= \frac{17}{18} \mu F$

$\therefore \quad C_{tot} = \frac{18}{17} = 1.06 \mu F$

In Parallel grouping

$C_{tot} = C_1 + C_2 + C_3$

$C_{tot} = 3 + 2 + 9$ $C_{tot} = 14 \mu F$

Example4. Three capacitors 1F, 2F, and 3F are joined in series first and then in parallel. Calculate the ratio of equivalent capacitance in two cases.

Solution: Given,

$C_1 = 1F, \quad C_2 = 2F, \quad C_3 = 3F$

In series grouping

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_S} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$$

$$\frac{1}{C_S} = \frac{11}{6}$$

$$\therefore C_S = \frac{6}{11} F$$

In Parallel grouping

$C_p = C_1 + C_2 + C_3$

$C_p = 1 + 2 + 3$ $C_p = 6F$

$\therefore$ Ratio $\frac{C_p}{C_S} = \frac{6}{\frac{6}{11}}$

or $\frac{C_p}{C_S} = 11$

UNIT-4: (CURRENT AND ELECTRICITY)

10.1 ELECTRICCURRENTANDITSUNITS

In a conductor, there are many free electrons. These electrons are in random motion but there is no net motion along the conductor. But if the two ends of a conductor are at different potentials, the charge will start flowing from one end of conductor to the other end. Therefore, the free electrons (charge) which were moving randomly will now move towards positive terminal of the battery and constitute a current. Hence a potential difference isalways needed to make charge move from one end of the conductor to the other end of the conductor.

Inaconductorthemotionofthefreeelectronsgiverisetotheelectriccurrentasshownin Fig. 10.1.

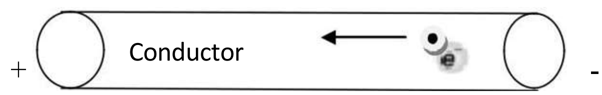


Figure10.1

Electric currentpassing through a conductoris *therateofflowofcharge passingthrough it.* If a charge ofq units passes through any cross section of the conductor in t seconds. The current flowing through the wire(I) is given by the formula

$$I = \frac{Charge}{time} = \frac{q}{t}$$

where I=theelectriccurrent

q=charge

t= timetaken

Unit: Ampere(A)

Intherelation

$$I = \frac{q}{t}$$

Ifthechargeismeasuredincoulombsandtimeismeasuredinsecondsthentheunit of currentwillbe ampere.

Where1ampere (A)=

Thedirectionofcurrentisthedirectionofflowofpositivechargei.e.oppositetothedirection of flow of electron.

OneAmpere:

Thecurrentflowingthroughtheconductorissaidtobeofoneampereifone coulomb of charge flows through the conductor in one second.

PotentialDifference(V)

It is the difference in electric potential between two points in an electriccircuit,thework that has to be done in transferring unit positive charge from one point to other.

Unit: Volts(V)

OneVolt:

Itisdefinedasenergyconsumption of onejoule1perelectricchargeofonecoulomb.

$$1 = 1$$

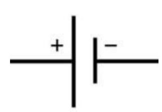
Onevoltisequaltocurrentof1amptimesresistanceof1ohm.

DirectCurrent

Directcurrentinan electricwireisthat whichflow inonlyonedirection. It is the unidirectional flow of current. Theelectric current flowing through asemi-conductor diode is an example of direct current. Direct current (DC) is produced by sources such as batteries,fuel cells and solar cells and cannot travel over long distances since it has more loss ofenergy.

The frequency ofDC is zero and it has a single polarity. In direct current the electron flow from negative end of the battery to the positive end of the battery.

Symbolof DCvoltagesource



ItcanbeshownbyFig.10.2.

Figure10.2

DC form is used in low voltage apparatus like charging batteries, cell phones, automotive apparatus, aircraft apparatus and other low voltage low current apparatus.

AC(Alternatingcurrent)

As shown in Fig. 10.3,AC is current that reverses the direction periodically and also has a magnitude that varies continuously with time.

AC is used in our homes. Power stations generate ac because it is easy to low andraise the voltage with the help of transformers.In North America the frequency of AC is 60Hz and in India it is 50 Hz. The AC in our home is sinusoidal in nature.

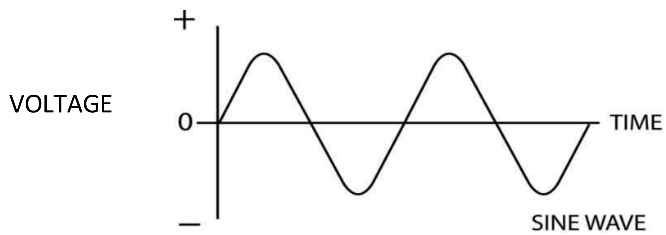
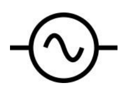


Figure10.3

Theradiofrequencycurrentinantennasandtransmissionlinesaretheexamplesof AC.

SymbolofAC



Itisproducedbyanalternatorandhasmorepowerandcanbeeasilytransferredfromone place to another.

10.2 OHM'SLAW

According to Ohm's law "*The current flowing through a conductor is always directly proportional to the potential difference between the two ends if the physical condition (temperature, pressure etc.) of the conductor remains the same*".

If I is the current passing through a conductor and and V is the potential difference between the ends of the conductor then

$$\mathbf{V \alpha I}$$

$$V=RI$$

$$\frac{V}{I}=R$$

Therefore, $$R=\frac{V}{I}=\frac{\text{PotentialDiffernce}}{\text{ElectricCurrent}}$$

whereRisaconstantandiscalledelectricresistance.

ThevalueofRdependsuponnature,dimensionandtemperatureofthe conductor.

V=IR

Therefore I=
Ifagraphisdrawnbetweencurrent (I)andthepotentialdifference(V)it will be a straight line for aconductor (Fig. 10.4).

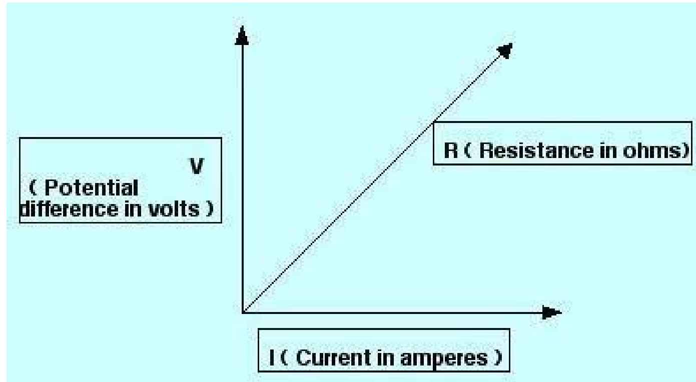


Figure10.4

10.3 RESISTANCE(R)

Theoppositiontotheflowofelectriccurrentinanelectriccircuitiscalledresistance. Therefore,itisthemeasureofthedifficultytopassanelectriccurrentthroughthecircuit.

R= =

IfV ismeasuredinvoltsandIismeasuredinamperesthentheresistanceR ismeasuredin ohms.

Symbol:

Unit:Ohms(Ω)

OneOhm:

1ohm=1

Therefore, one ohm is the resistance of conductor in which a current of one ampere flowsthrough itwhenthepotentialdifferenceofonevoltismaintainedbetween itstwo ends.

SpecificResistance(DefinitionandUnits)

Theresistanceofaconductordependsonfollowing factors;

(i)Theresistanceofagivenconductorisdirectlyproportionaltoitslengthi.e.

$$R \propto l \text{............} \qquad (1)$$

ii)Theresistanceofagivenconductorisinverselyproportionaltoitsareaofcross-section.

$$R \propto \frac{1}{A} \text{..................................} \qquad (2)$$

By combining equation (1) and (2), we get

$$R \propto \frac{l}{A}$$

or

$$R = \rho \frac{l}{A}$$

where *ρ* (rho) is a constant and known as specific resistance or resistivity of the material. The resistivity of a material does not depend on its length or thickness. It depends on the nature of the material.

If $l = 1$ m *and* $A = 1 m^2$ *then from above equation*

$$\rho = R$$

Thus resistivity of the material is the resistance of a conductor having unit length and unit area of cross- section.

Units: Ohm-**m(Ωm)**

Conductivity

It is the degree to which an object conducts electricity. This is the reciprocal of the resistivity,

$$\sigma = \frac{1}{\rho}$$

Where, **σ** is the conductivity and **ρ** is the resistivity of the conductor.
Unit: Siemens per meter or mho per meter

Conductance(G)

It is the reciprocal of the resistance and it is a measure of ease with which the current flows through a substance.

$$G = \frac{1}{R}$$

where G = Conductance
R = Resistance

Unit: mho

10.4 COMBINATION OF RESISTANCES

1. Series combination

The resistance are said to be connected in series if the same current passes through all the resistances and the potential difference is different across each resistance.

Let three resistances R_1, R_2, R_3 be connected in series as shown in the Fig. 10.5

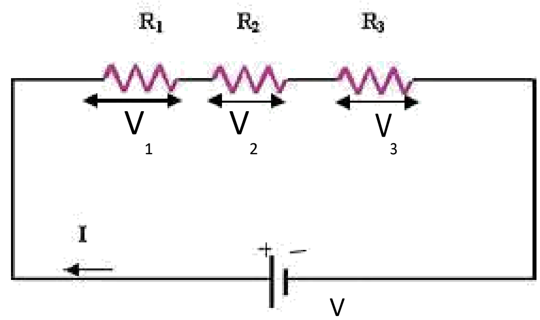


Figure10.5

Let

V=Voltageappliedacrosstheseriescombination I =
Current passing through the circuit
ClearlycurrentIissamethroughoutthecircuit

Let V_1, V_2, V_3 be the potential difference across R_1, R_2, R_3 respectively. Then, according to Ohm's law

$V=IR$

whereRisthetotalresistancein series

Now

$V = V_1 + V_2 + V_3$--------------- (1)

ThenbyOhm'slaw

$V_1 = I R_1$
$V_2 = IR_2$
$V_3 = IR_3$

PuttingthevaluesofV1,V2andV3inequation(1)we
get$IR = IR_1 + IR_2 + IR_3$ IR
$= I (R_1 + R_2 + R_3)$
$R = (R_1 + R_2 + R_3)$

Thus the combined resistances when they are connected in series is the sum total of the individual resistances.

2. ParallelCombination

The resistances are said to be connected in parallel if the potential difference acrosseach resistance is the same but the current passing through each resistance is different.

Letthere be three resistances R_1, R_2, R_3 connected in parallelas shown in Fig. 10.6.One end of each resistance is connected to pointA and the otherend of each resistance is connected to the point B.

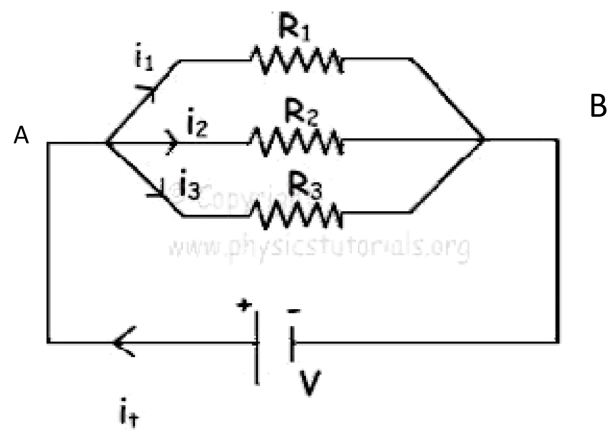


Figure10.6

Let

V=PotentialDifferenceappliedacrossAandB

Clearly, potentialdifferenceVissameacrosseachresistance. Let

I= total current flowing in the circuit.

R=totalresistanceofthecircuit

LetI_1, I_2, I_3 bethecurrentpassing through theresistancesR_1,R_2,R_3 respectively.

From Ohm's law applied to the whole circuit

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$

Now we have,

$$I = I_1 + I_2 + I_3 \text{ ---------------------------------- } (2)$$

Puttingthevaluesof$I$,I_1,I_2,I_3intheequation(2)

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$V\frac{1}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

Or

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Thus we can say that if the resistances are connected in parallel, then the reciprocal of the equivalentresistanceisequaltothesumofreciprocalsofindividualresistancesinthecircuit.

10.5 HEATING EFFECT OF ELECTRIC CURRENT

Whenanelectriccurrentispassedthroughaconductor,theconductorbecomeshot after some time and produces heat. This happens due to the conversion of some electric energy passing through theconductorinto heatenergy. Thiseffectofelectriccurrentiscalled heating effect of current.

Theheatingeffectofcurrentwasstudiedexperimentallyby Joulein1941.Afterdoing this experiments, Joule came to the conclusion that the heat produced in a conductor is directly proportional to the product of square of current (I^2), resistance of the conductor (R) and the time (t) for which current is passed. Thus,

$$H=I^2Rt$$

DerivationofFormula

To calculate the heat produced in a conductor, consider current I is flowing through a conductor of resistance R fortime t. Also considerthat the potential difference applied across its two ends is V.

Now,totalamountofwork donein movingachargeqfrompointAtopointBisgivenby:

$$W=q\times V \text{ ----------------------------------- } (1)$$

Now,weknowthatcharge=currentxtime

$$\text{or} \; q=I\times t$$

$$\text{and} \; V=I\times R \text{(Ohm's law)}$$

PuttingthevaluesofqandVinequation(1),weget

$$W=(I\times t)\times(I\times R)$$

$$\text{or} \; W=I_2Rt$$

Now,assumingthatalltheworkdoneisconvertedintoheatenergywecanreplacesymbolof 'workdone'withthatof'heatproduced'.So,

$$H=I^2Rt$$

ApplicationsofHeatingEffectofCurrent

Theheatingeffectofcurrentisusedinvariouselectricalheatingappliances suchas electric bulb, electric iron, room heaters, geysers, electric fuse etc.

10.6 ELECTRICPOWER

Electricpoweristherate, perunittime, atwhichelectricenergyistransferredbyan electric circuit.

Let P=Electricpower P

$= W/t$

$P=VI$

Where, VistheappliedvoltageandIisthecurrentflowing through thecircuit. SIunitof power is Volt (V).

Now $P=VI$

If, V=1Volt (1V)andI = 1Ampere (1A),then,

P =1Watt

Thus, powerissaid tobe1watt,ifapotentialdifferenceof1 voltcauses1ampereof current to flow through the circuit.

BiggerunitsofelectricpowerareKiloWatt(KW)andMegaWatt (MW)

10.7 KIRCHHOFF'SLAWS

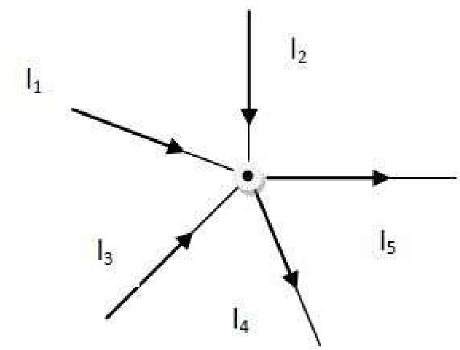
These two rules are commonly known as: Kirchhoff's circuit laws with one of Kirchhoff's laws dealing with the current flowing around a closed circuit, Kirchhoff'sCurrent law (KCL) while the other law deals with the voltage sources present in a closed circuit, Kirchhoff's Voltage law, (KVL).

(i) Kirchhoff'sFirstLaw(Kirchhoff'sCurrentLaw)KCL

The law states that "The *algebraic sum of all the currents meeting at any junction point in an electric circuit is zero*"

$$\Sigma I = 0$$

Let us suppose the currents I_1, I_2,I_3entering the junction are all positives in value and the two currentsI_4, I_5areleavingthejunctionarenegativein values (Fig. 10.7), then according to KCL



$$I_1+I_2+I_3-I_4-I_5=0 \quad I_1+I_2+I_3 = I_4+I_5$$

Sumofincomingcurrents= sumofoutgoing currents

Figure10.7

(ii) Kirchhoff'sSecondLaw (Kirchhoff'sVoltageLaw)KVL

The lawstatesthat"*Inany closedloopof acircuit,thealgebraic sumofproducts of the resistances and currents plus the algebraic sum of all the e.m.f. in that circuit is zero*".

In any closedcircuit;$\Sigma E+\Sigma IR=0$

Hereweusetwosignconventions(Fig.10.8).

1. If we go from negative terminal of the battery to the positive terminal thenthere is rise in potential and it is considered positive. And if we go from positive terminal to negative terminal, there is fall of potential and it is considered as negative.

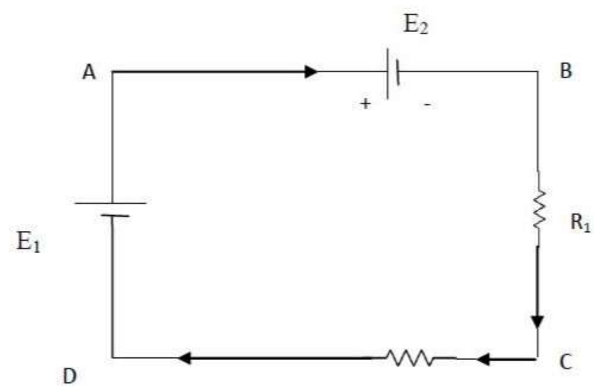


Figure10.8

2. Ifwegowith thecurrent,voltagedrop isnegativeandifwego againstthecurrent, the voltage drop is positive.

IntheclosedloopABCDusing KVLweget

$$-E_2-IR_1-IR_2+E_1=0$$

SolvedNumericals

Example 1.Anemfsource of6Visconnected to aresistive lamp and a currentof2 amperes flows. What is the resistance of lamp?

Solution. Given, V=6V and I=2A

FromOhm'slaw,weknow, $V=IR$ or $R=V/I$

$R=6/2$ **$=3\Omega$**

Example2. Anelectricfanhasaresistanceof100ohms.Itispluggedintopotential difference of 220 V. How much current passes through the fan?

Solution. Given, R = 100 ohms and V = 220 V

We know, $I = V/R = 220/100$

Therefore $I=2.2A$

Example3.Calculatethetotalresistanceifthreeresistancesof1 ohm,2ohmand3ohm are connected in series.

Solution. Givenresistances,R_1=1ohm,

R_2=2ohm

R_3=3ohm

Weknowthatinseriescombination;$R=R_1+R_2+R_3$

Therefore $R=1+2+3=6$ohm

Example4. Calculatethetotalresistanceifthreeresistancesof4 ohm,1ohmand6ohm are connected in parallel.

Solution. Given, R_1=4ohm

R_2=1ohmR_3

=6 ohm

Formformulaweknowinparallelcombination

$$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

Hence $$\frac{1}{R}=\frac{1}{4}+\frac{1}{1}+\frac{1}{6}=\frac{3+12+2}{12}=\frac{17}{12}$$

Therefore, Totalresistance, $R=\frac{12}{17}$ohm

UNIT -5: (ELECTROMAGNETISM)

11.1 ELECTROMAGNETISM

Electromagnetismormagnetismingeneralisthestudyofproductionofmagneticfield when current is passed through a conductor. Various terms associated with magnetism are;

Magnetization(I)

Itrepresentstheextenttowhichamaterialismagnetizedwhenplacedinamagnetic field. It is given by magnetic moment per unit volume of material.

$$I = \frac{M}{V}$$

where,MismagneticmomentandVisvolumeofthematerial.

Unit:Ampere/meter

MagneticIntensity(H):

Itisthecapabilityofmagneticfieldtomagnetizeamagneticmaterial.

MagneticPermeability(μ):

Itisproperty ofmaterialanddefinedasthedegreetowhichmagneticlinesofforce can penetrate the medium.

Magneticsusceptibility(χ):

Itisapropertywhichdetermineshow easilyaspecimencanbemagnetised. Itis given by ratio of magnetization and magnetic Intensity.

$$\chi = \frac{I}{H}$$

TypesofMagneticMaterials:

Onthebasisofbehaviourofmagneticmaterialinmagneticfield, thematerialsare divided in to three categories:

1. **Diamagneticmaterials:**

The materials when placed in magnetic field, acquire magnetism opposite to the directionofmagneticfield. Themagneticdipoles inthesesubstances tendtoalignoppositeto the applied field and tends to repel the external field around it.

- Diamagneticsubstanceshavetendencytomovefromstrongertotheweakermagnetic field.
- Whenrodofdiamagneticmaterialisplacedinmagneticfield, italignsperpendicular to the magnetic field.
- Permeabilityofdiamagneticmaterialis<1.

Examples; gold, water, mercury, graphite, lead etc

2. Paramagneticmaterials:

Paramagnetic substances are those which get weakly magnetized when placed in an external magnetic field. These materials show weak attraction in magnetic field. Themagnetic dipoles in the magnetic materials tend to align along the applied magnetic field. Such materials show weak feeble magnetization and the magnetization disappears as soon as the external field is removed.

- Permeabilityofparmagneticmaterialis> 1.
- Themagnetization(**I**)ofsuchmaterialsdependentontheexternalmagneticfield(**B**) and temperature (T) as:

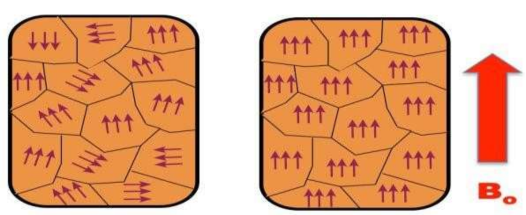
$$I = C\frac{B}{T}$$

WhereCistheCurieconstant.

Examples:sodium,platinum,liquidoxygen,saltsofironandnickel.

Ferromagneticmaterials:

Ferromagnetic substances are those which get strongly magnetized when placed in an external magnetic field. They exhibit the strongest attraction in magnetic field. Magnetic dipoles in these materials are arranged into domains.



(a) (b)

Figure11.1

These domains are usually randomly orientedas shown in Fig. 11.1 (a) and net magnetism is zero in the absence of magnetic field. When an external field is applied, the domains reorient themselves to reinforce the external field as shown in Fig. 11.1 (b) and produce a strong internal magnetic field that is along the external field.

Thesematerialsshowmagnetismonremovalofmagneticfield.

Examplesareiron, cobalt, nickel,neodymiumandtheiralloys. Theseareusuallyhighly ferromagnetic and are used to make permanent magnets.

11.2 MAGNETIC FIELD

Thespacearoundamagneticmaterialoramovingelectricchargewithinwhichthe force of magnetism can be experienced.

Unit:Tesla(Wb/m^2)

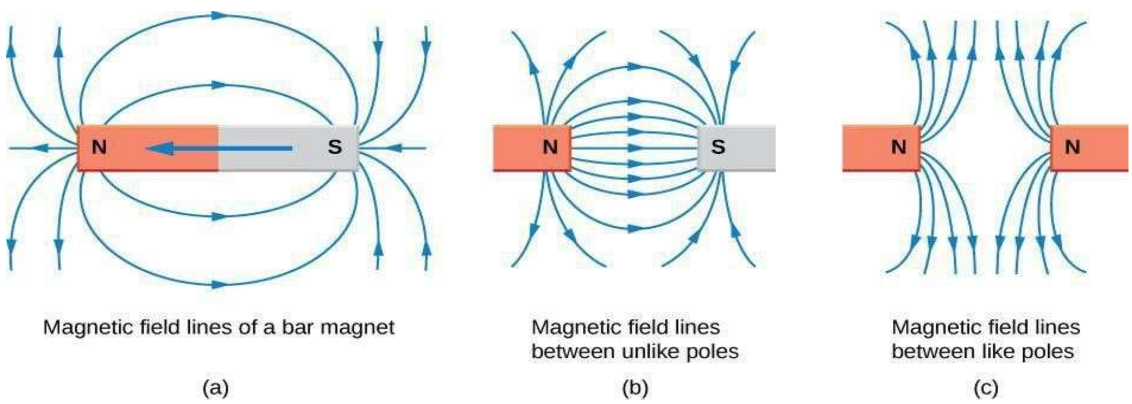


Figure11.2

Magneticlinesofforce:

Curvedlinesusedtorepresentamagneticfield, drawnsuchthatthenumberoflines relates to the magnetic field's strength at a given point(Fig. 11.2).

Propertiesofmagneticlinesof force

(i) The magnetic field lines of a magnet form continuous closed loops.
(ii) The tangent to the field line at a given point represents the direction of the net magnetic field B at that point.
(iii) Larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B.
(iv) Their density decreases with increasing distance from the poles.
(v) The magnetic field lines do not intersect with each other.
(vi) They flow from the South Pole to the North Pole within a material and North Pole to South Pole in air.

Magneticflux:

The total number of magnetic field lines crossing through given surface areaS held perpendicular to direction of magnetic field B.

$\phi = BSCos\theta$

Unit:TheSIunitofmagneticfluxistheweber(Wb)

MagneticIntensity:

It is the amount of magnetic flux in a unit area perpendicular to the direction of magnetic flow.

11.3 ELECTROMAGNETICINDUCTION

The induction of an electromotive force by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field.is called **electromagnetic induction**.

Itisusedinelectricalmotor, generatoretc.togenerateelectricity.

******

UNIT-6

SEMICONDUCTOR PHYSICS

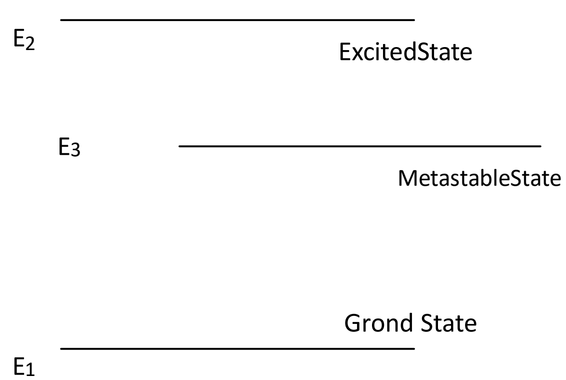
12.1 ENERGYLEVELANDENERGYBANDS

EnergyLevels:

Inanatom, electronscannotrevolveinanydirection, butareconfinedtowelldefined energy states. These states are called ***energy levels***.

Therearethreetypesofenergylevels:

1. **Ground level:** This refers to the lowest energy state in the system(E_1).Thus the completely de-excited atoms would occupy this level.



2. **Excited level:** any level above the groundstate is excited state (E_2). Theatom can stay in excitedstateonly for10^{-8} s.Afterthistimetheatomwillloseitsenergy in theform of radiation and come back to ground state.

3. **Metastablelevel:**Thislevelliesin between theexcitedandground levels(E_3). Its lifetime is 100 times more than excited state.

EnergyBands:

When two atoms are brought closer to form a solid, the energy levels getmodified due to mutual interactions.Each energy level split into two levels, one having energy higher thanthe original level and another having lower energy.

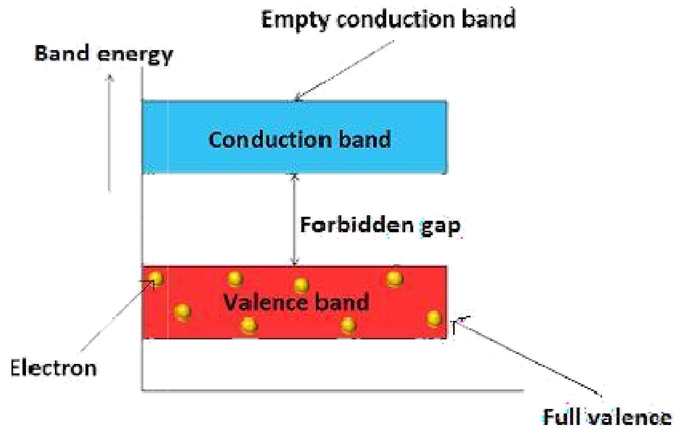


Figure12.1

Now when a large number of atoms (n) come closer to each other, each energy level splits into a large number of levels. As a result a large number of discrete but closely spaced energy levels are formed. These are called Energy Bands. The inner shells however remain unaffected by neighbouring atoms. Because they are shielded by the outer electrons of their own atoms.

The highest energy band occupied by the valence electrons is called the **valenceband**.Above this band there lies an empty band called the **conduction band.** These bands are separated by an energy gap known as **ForbiddenGap(E_g)**asshowninFig.12.1.

12.2 TYPESOFMATERIALS

Onthebasisoftheforbiddengap(E_g),thematerialcanbedividedintofollowingcategories (Fig.12.2).

Insulators: Thesearepoorconductorsofelectricity.ForbiddengapforthesematerialsisE$_g$ = 5 - 6eV.Theenergy gap between valence band and conduction band is very large. Hence valence electrons will not be freed and no current will flow. Examples are paper, wood, plastics.

Conductors: Metals or good conductors are those substances which can conduct heat and electricity through them easily as there are many free electrons. In case of conductors E_g =0i.e.valencebandandtheconduction band overlap each other. Examples are Copper, aluminium, gold etc.

Semiconductors: Theconductivity ofasemiconductorliesbetween thatofconductorsand insulators. In case of semiconductors, $E_g$is of the order of 1 -2 eV.

Atabsolute zero temperature, the conduction band is totally empty and there isno flowofcurrent.Sothesematerialsactasinsulatorsatroomtemperature. Butatthehigher temperature, some valence electrons acquire sufficient energy to go in the conduction band.So at higher temperatures these materials start working as conductors. Even a small electric field can cause a flow of current in such materials. Examples are Silicon (Si), Germenium (Ge) etc.

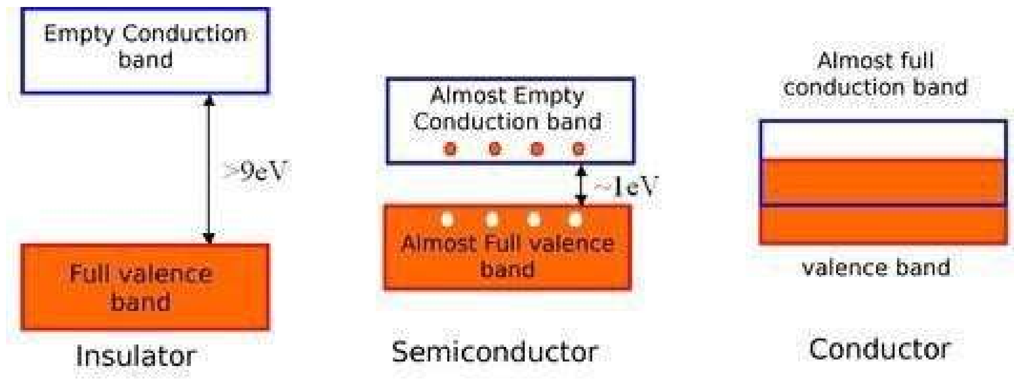


Figure12.2

12.3 INTRINSICANDEXTRINSICSEMICONDUCTORS

Intrinsic Semiconductors: A semiconductor, which is quite pure and completely free from any impurity, is called an intrinsic semiconductor. E.g. Silicon (Si) and Germanium (Ge).

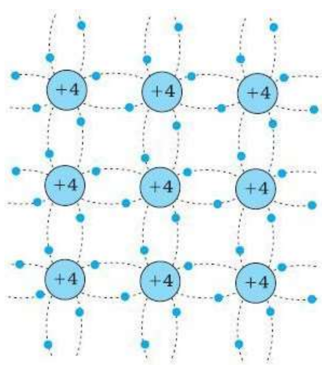


Figure12.3

They have four valence electrons. Each of the four electrons form *covalent bond* with neighboring four atoms. By forming such covalent bonds, there is no free electron at absolute zero temperature. At room temperature some electrons break away from the covalent bond and enter into the conduction band.Each electron leaves behind a vacancy known as hole.

Henceinpuresemiconductorsbothelectrons andholesconstitutecurrentandthenumbersofthese twotypesofchargecarriersareequali.e.$n_e = n_h$

ExtrinsicSemiconductors

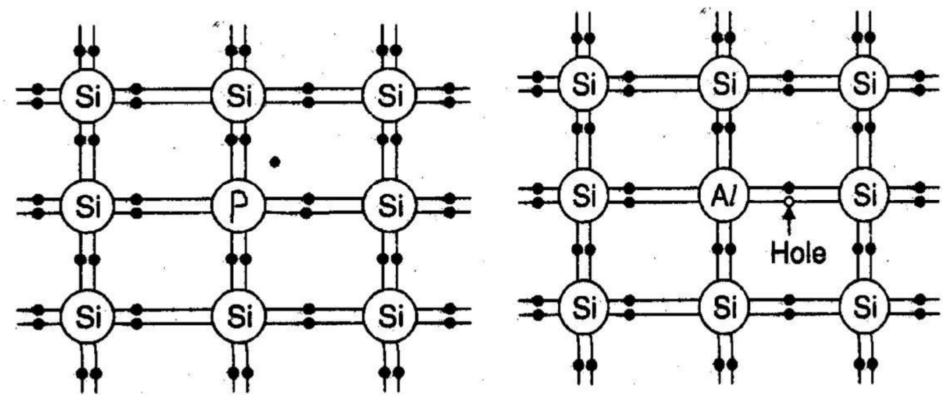
A doped semiconductor is called an extrinsic semiconductor. The addition of a desirable impurity to a **semiconductor is called doping and the impurity** atoms added are called dopants.

n-TypeSemiconductor:

When a small amount of pentavalent impurity (e.g. Phosphorous, Arsenic etc.) is added to an intrinsic semiconductor (Si or Ge), it provides a large numbers of free electrons. The semiconductor is then, called n-type semiconductor.

Because impurity atom has five valence electrons, four of these will form covalent bonds, but one excess electron will be left free. Hence the current carriers are electrons. Therefore majority carriers are negatively charge electrons while the holes are minority carriers.

Inann-typesemiconductor, numberofelectronsismuchlargerthanthenumberofholes, i.e. $n_e >> n_h$



n-type **p-type**

Figure12.4

p-TypeSemiconductor:

When a small amount of trivalent impurity (e.g. Boron, Aluminum etc.) is added to intrinsic semiconductor, it creates a large number of holes in valence band. The semiconductor is called a p-type semiconductor.

When atrivalent impurity is added tosemiconductor, its three valenceelectrons form covalent bonds with three neighbouring atoms, while the fourth bond has a deficiency of electron. Thus there is a vacancy, which acts as a hole that tends to accept electrons.

The number of holes is greater than the number of electrons,*i.e.* $n_h >> n_e$

Hence, in p-type semiconductors, holes are the majority *carriers* and electrons arc the minority carriers.

p-nJunctionDiode

Asingle crystal of silicon or germanium that has been doped in such a way that halfof it is a p-type and the other half an n-type semi-conductor is known as ap-n junction diode. The junction is called p-n junction as shown in Fig.12.5.

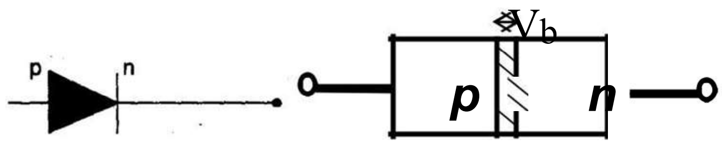


Figure12.5

Characteristicsofp-nJunctionDiode

The graph showing the variation ofthe currentflowing through the junction, when the voltage is applied across thejunction diode inforwardbiased andreversebiased, is knownas characteristic curve of a p-n junction diode.

Forward bias characteristic: The p-n junction diode is said to be forward biased if the positive terminal of battery is connected to the p-type and the negative terminal to the n-type of semiconductor as shown in Fig. 12.6.

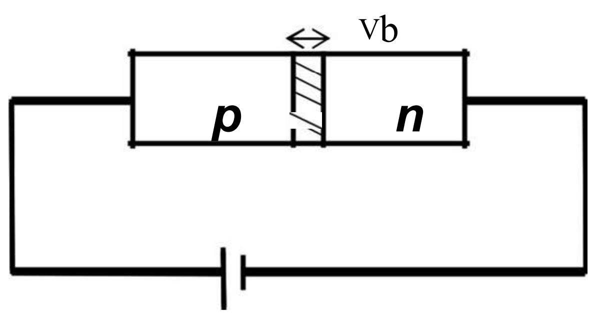
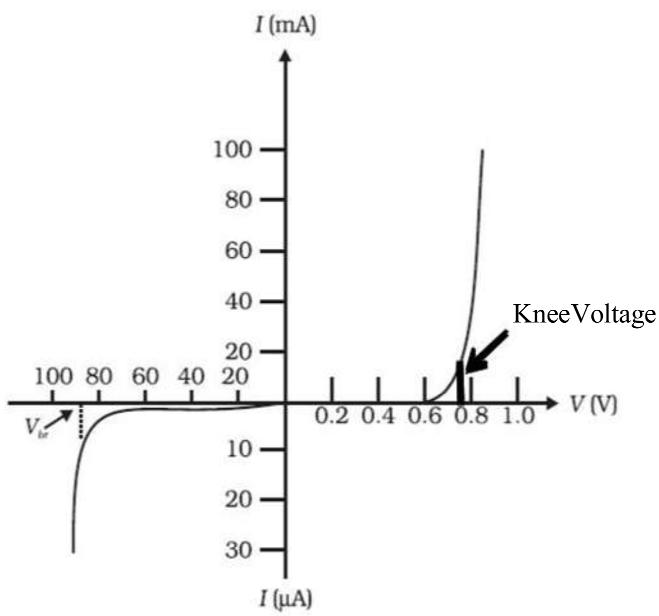


Figure12.6



Let V is the voltage applied. This pushes the majoritycarriers, the holes in the p-type and electrons in the n-type towards the p-n junction.

If $V > V_B$, then the majority carriers from both sides are able to diffuse acrossthejunction and a current is set up in the circuit. This process decreases the thickness of the depletion layers. The diodeoffers alowresistance to the flow of current.

A minimum amount of voltage required so that a current start flowing is known as the knee voltage. The current starts

Figure12.7

Reversebias characteristic:

The p-n junction diode is said to be reverse biased if the negative terminal of the external source is connected to the p-type and the positive terminal to the n-type of semiconductor as shown in Fig 12.8.

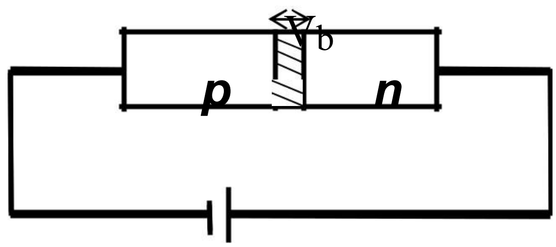


Figure12.8

The external voltage pulls the majority carriers holes in the p-type crystal and the electrons in the n-type crystal away from the junction. This increases the width of depletion layer. Thediodeoffersvery high resistanceandno currentissetup acrosstheJunction dueto majority carriers.However a small currentmay be there acrossthe junction due to minority carriers.Itiscalledleakage*current*(I_S).

12.4 DIODEASARECTIFIER

Therectifierisanelectronicdeviceusedtoconvertalternatingcurrent(AC)intodirect current (DC).

Halfwaverectifier:

Half wave rectifier convert AC into DC for only half of theinput cycle. Thecircuit diagramforhalfwaverectifierusingthep-ndiodeisasshown.Duringthefirsthalfcycleof ACthediodeoperates under aforwardbias andcurrent flowsthroughtheloadR_L.During theotherhalf,thediodebecomesreversebiasandnocurrentflowsthroughtheloadR_L.Thus wegetarectified,unidirectionalcurrentacross$R_L$andonlyhalfoftheACsignalwaveis rectified. The half wave rectifier gives output only for half cycle, hence power loss is high.

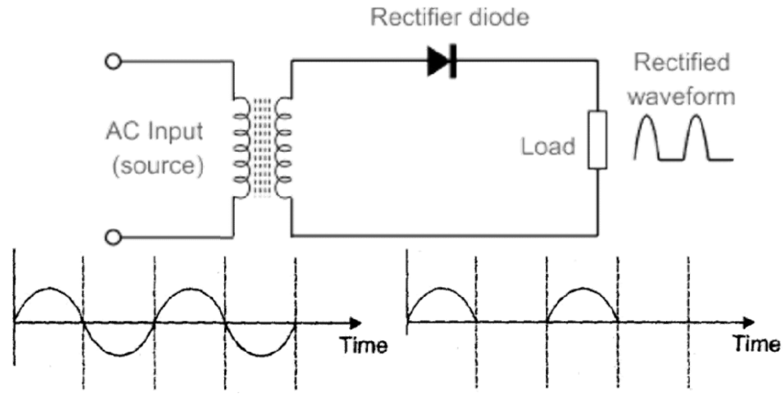


Figure12.9

Full waverectifier:

FullwaverectifierconvertsAC in toDCforcompletecycleofinputwave.Thecircuit diagram for full wave rectifier is shown. The center tap transformer is used. Two diodes are connected across the secondary of the transformer, the middle point of which is tapped at T. During thefirst half of theAC cycle, oneendofthe secondary sayA becomes positive andB becomes negative. Diode D_1 is forward biased and diode D_2 is reverse bias. Thus a current flows through the diode D_1.

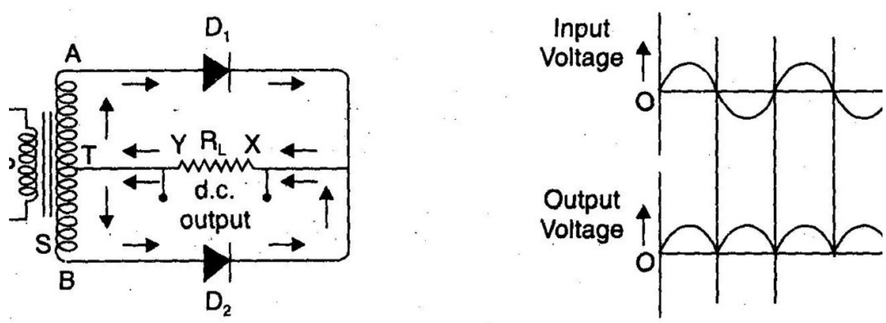


Figure12.10

During the other half of AC cycle, end B becomes positive and the end A negativeand the current flows through the diode D_2. Thus during both halves, the current through the load $R_L$is in the same direction and full wave rectification of AC is achieved.

12.5 SEMICONDUCTORTRANSISTOR

The transistor is composed of three semiconductor elements. The three elements are combined in such a way that if n-type semiconductor is sandwiched between two p-type semiconductors. This is known as p-n-p transistor. So basically transistor is combination of two pn-junctions joined back to back (Fig. 12.11).

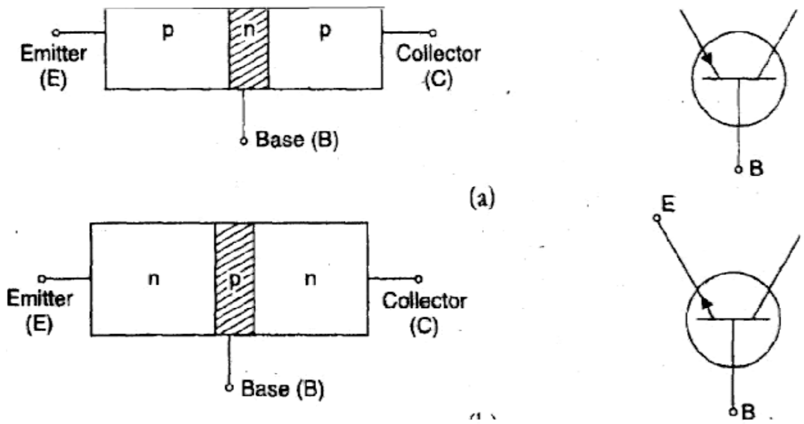


Figure12.11

If p-type semiconductor is sandwiched between two n-type semiconductors then this is known as n-p-n transistor. In the circuit symbols of a transistor, only emitter has an arrow to indicate that it is the supplier electrode. It also indicates the direction of flow of current.

- The three elements of the transistor rare; emitter(E), collector(C)and base(B).
- The emitter supplies the majority carriers for transistor current flow. The collector collects current and the base controls the passage of electrons from the emitter to collector.
- The doping level in the emitter is more than in the collector.
- The base is thin and lightly doped.
- Collector is moderately doped.
- Area of emitter is moderate ,base is minimum and collector is maximum.
- In normal operation of a transistor, the emitter-base junction is always forward-biased whereas the collector-base junction is reverse-biased.

******

UNIT-7

MODERN PHYSICS

13.1 LASER

LASER is an acronym for **Light Amplification by Stimulated Emission of Radiation**. It is a beam of light which is coherent, monochromatic, highly directional and very intense.

Energy Level : In an atom, the electrons are confined to well defined energy states. These states are called as energy level(Fig. 13.1).

There are three type of energy levels:

1. **Ground level:**Thisreferstothelowestenergystateinthesystem(E_1).Thecompletely de-excited atoms would occupy this level.

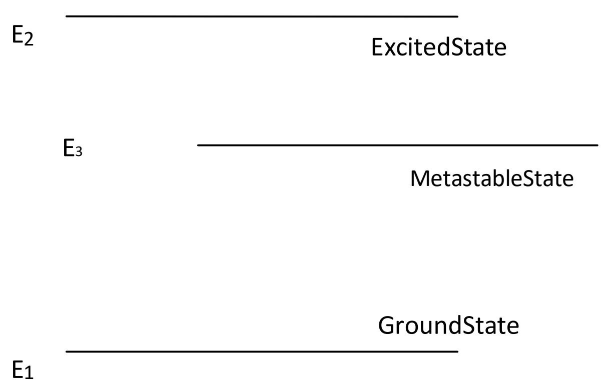


Figure13.1 Energylevels

2. **Excited level:** Any level above the ground state is excited state (E_2). The atom can stayin excited state only for a very short time varying from $10^{-8}$to 10^{-10}s. After this time the atom will lose its energy in the form of radiations and come back to ground state.
3. **Metastable level:** This level lies in between the excited and ground levels (E_3). Its lifetime is 100 times more than excited state and atom can stay in this state for a longer time.

TheEmissionProcess

When a material isenergized by some radiations, the atomsofthe material getexcited to the higher state from ground state. These excited atoms may lose energy and come backto ground state. The energy loss may be in the form of heat, light or X-rays etc. This process may takes place in two ways:

I. SpontaneousEmission:

Spontaneous emission is the process of light emission in which the atoms in excited state (E_1)comes back to ground state(E_0)after10^{-8}seconds, without any external radiation(see Fig.13.2).The atoms in excited state, release **radiation of energy hν =E_1** - E_0 in the form of photons. These photons are emitted in random directions.

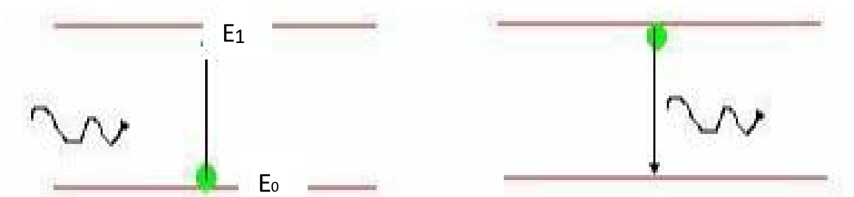


Figure13.2 Spontaneousemissionprocess

II. StimulatedEmission:

Ifexcitedatomisirradiatedwithaphoton **having energy hν** = E_1 - E_0 before spontaneous emission process, then the excited atom will lose the energy in the form of two photon as shown in Fig.13.3.Thisprocessoccursin suchawaythatthe incident photon and the emitted photon are foundtobemovingwithsamemomentumandphase. This kind of emission is called stimulated emission.

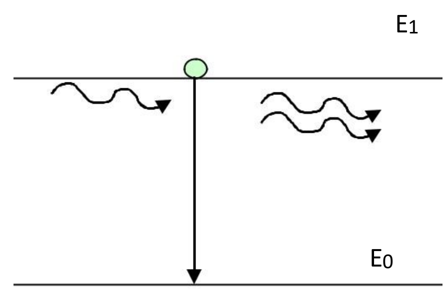


Figure13.3 Stimulatedemissionprocess

PopulationInversion:

Inamaterial,whenthenumberofatomsinexcitedstate(N_2)becomesmorethanthe number of atoms in ground state (N_1), this condition is known as Population Inversion. This condition is must for stimulated emission.

Characteristicsof Laser

Laserlighthasfouruniquecharacteristicsthatdifferentiateitfromordinarylight:

a) Coherence

The photons emitted from ordinary light sources have different phases and hence non-coherent.WhileinLaserallthe emittedphotonshavesamephaseorconstantphase difference. Thus the laser light is highly coherent in nature. Becauseofthiscoherence, alarge amount of power can be concentrated in a narrow space.

b) Monochromatic

Inlaser, allthephotonsemittedhavethesamefrequency,orwavelength.Hence, thelaser light has single wavelength or color. Therefore, laser light covers a very narrow range of frequencies or wavelengths. Hence the light emitted by a laser is highly monochromatic.

c) Directionality

Inordinarylightsources(lamp, torch), photonswilltravelinrandomdirection. Therefore, these light sources emit light in all directions. But, in laser, all photons will travel in same direction. Therefore, laser emits light only in one direction. This is called directionality of laser light. As a result, a laser beam can travel to long distances without spreading.

If an ordinary light travels a distance of 2 km,it spreads to about 2 km in diameter. Onthe other hand, if a laser light travels a distance of 2 km, it spreads by less than 2 cm.

d) HighIntensity

In laser, the light spreads in small region of space and in a small wavelength range. Hence, laser light has greater intensity when compared to the ordinary light. Even a 1 milli watt laser would appear many thousand times more intense than100Watt ordinary lamp.

ApplicationsofLasers:

- Laserwelding:Laserscan beused forspotwelding,seamwelding,inertgaslaser welding and welding of non-metals.
- Laser cutting: Metals can be cutwith output power of atleast 100 W to 500 W. Wide range of materials can be cut e-g. paper, cloth, plywood, glass, ceremics, sheet metal like steel, titanium, aluminium etc.
- Laserdrilling:Lasersareusedforfinedrilling
- Lasersareusedforaccuratemeasurementoftheorderof0.1 mtotheextentofdistant object.
- Lasersareusedtoproducethermonuclearfusion.
- Theseareusedtostudythechemicalprocess, natureofchemicalbonds,structureof molecule and scattering.
- Longdistancecommunicationbyusingopticalfibreandlaserisveryefficient.
- Inmedicine, lasersareusedtostudymanybiologicalsamples, treatmentof leverand to remove tumors.
- Laserisusedforprinting. Laserprintersareveryfastandefficient. Thequalityisvery high.
- In computers, weuselaserdisc. InCDwriter, atiny laserbeamburnsspoton the compact disc.

13.2 OPTICALFIBRE

An optical fibre consists of a very thin core made of glass or silica having a radius of the order ofmicrometers (10^{-6} m).The core is covered by athin layerof cladding material of lowerrefractive index. Such optical fibres can transmita light beam from one end to the other without significant energy loss. These are generally made from transparent materials such as glass (silica) or glass like polymers.

The branch of physics dealing with the propagation of light through optical fibres is known as ***fibreoptics***

Principle:Itisbasedonthephenomenonoftotalinternalreflectionsattheglassorsilica boundary. The light will reach at other end even if the fibre is bend or twisted.

If ray of light travelling from a denser medium into a rarer medium, and the angle of incidence is greater than the critical angle, the ray is totally reflected back into the same media. This phenomenon is called as **total internal reflection.**

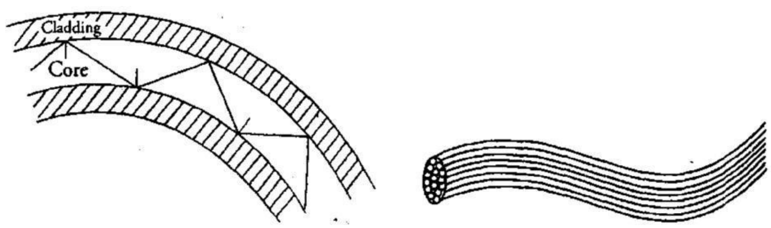


Figure13.4 Schematicofopticalfibre

FibreTypes

On the basis of mode of propagation the fibre can be classifiedas:

Mono mode fibre: It has a verynarrow core of diameter about 8-**12 μm or less and Multi mode fibre:**It has acore of **the cladding is relatively big 125 μm as** relatively large diameter such as 50-200 shown in Fig. 13.5(a).As then ame**μm as shown in** Fig.13.5(b).As the name implies, mono mode fibre sustains only one suggests the multimode fibre contain many mode of propagation that is why it is also hundreds of modes of propagation known as single mode fibre. simultaneously. Thesignalsdo not intermixwitheachother.Thisismost commonly used optical fibre.

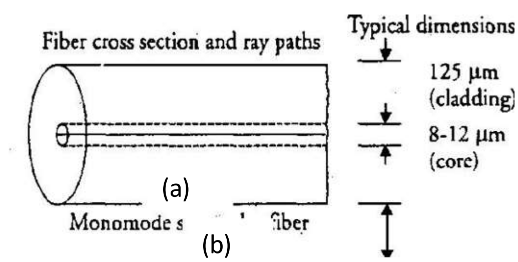
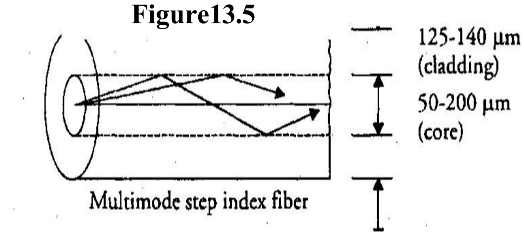


Figure13.5



Numerical Aperture (NA): It is the light collecting ability of an optical fiber. It depends on difference in refractive index of core and cladding.Generally,valueofNArangesfrom 0.1 to 0.5 for most of the commonly used optical fibres.

Applications of OpticalFibres:

- With the help of light pipes made up of flexible optical fibres, it is possible to examine the inaccessible parts of equipment or of the human body. Forexample in endoscopy, a patient's stomach can be viewed by inserting one end of a light pipe into the stomach through mouth.
- Opticalfibresarealsousedfortransmittingandreceivingelectricalsignalsthatare converted to light by transducers.
- These are used as transmission medium to transmit communication signals at high data rates over long distances. For example, more than 100000 telephone signalsat data rate of Gigabits/sec can be simultaneously transmitted through a typical single pair ofoptical fibre.
- Optical fibres are also being extensively used for cable TV networks and localarea networks (LAN) in premises.

Thequalityofthesignalstransmittedwithopticalfibresismuchbetterthanother conventional methods.

13.3 NANOTECHNOLOGY

It is the branch of technology that deals with use of nanomaterials with dimensions less than 100 nanometres, especially the manipulation of individual atoms and molecules.

Nanomaterials:

These are materials with any dimension in the nanoscale (1 nm to 100 nm). These materials are very reactive and exhibit unique physical, chemical and biological properties due to high surface-to-volume ratio.

Example: Carbon nanotube, nano particle, quantum dots, nano plymers, nano shell, nano pores,nano rod, nanowires, nanopowder, fullerene, etc.

ApplicationsofNanotechnology

Nanomaterials are of interest because oftheir unique optical, magnetic, electrical, and other properties. These emergent properties have the potential for great impacts inelectronics, medicine, and other fields.

- **Medicine**: Nanotechnology based drugs are being used to treat dangerous diseases like cancers and prevent health issues more effectively, as customized nano particles can deliver drugs directly to diseased cells in the body. New nanoparticles based chemotherapy drugs that can be delivered directly to cancer cells for better treatment are under development.

- **Electronics:** Electronic devices made with nano-fabrication techniques help in reducing weight and power consumption. This also improves display screens on electronic devices and increasing the density of memory chips. Nanotechnology can help to reduce the sizeof transistors and other components used in integrated circuits.

- **Food Industry**:Developing new nanomaterialswillnotonly make a difference in the tasteoffood, butalsoinimprovethefoodproduction, nutrientvalueandpreservation.
- **FuelCells:** Nanotechnology is being used to reduce the costof catalysts, used in fuelcells to produce hydrogen ions from fuel such as methanol. Nanomaterials are also being developed to improve the efficiency of membranes used in fuel cells.
- **Solar Cells:** Nano technology based solar cells can be manufactured at significantly lower cost with better efficiency as compared to conventional solar cells.
- **Space:**Advancementsindevelopmentofnano-compositesmakelightweightspacecrafts. Carbon nano tubes based cables have been proposed for the space elevators.
- **Fuels:** Nano technology can be used for production of fuels from low grade raw materials which are economical and also increase the efficiency of engines.
- **Catalyst:** Nano particles have a greater surface area to interact with the reacting chemicals than catalysts made up of larger particles. This allows more chemicals to interact with the catalyst simultaneously and hence makes the catalyst more effective.
- **Chemical Sensors:** Nanotechnology based sensors can detect very small amounts of chemical vapors. Various types of nanostructures such as carbon nanotubes, grapheme, zinc oxide nanowires can be used as detecting elements in nanotechnology based sensors.
- **Fabric:** Making composite fabric with nano-sized particles or fibres allows improvement of fabric properties without a significant increase in weight, thickness, or stiffness.
- **Environment:** Nanotechnology is being used in cleaning water and existing pollution, improving manufacturing methods to reduce the generation of new pollution, and making alternative energy sources more cost effective.

******